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FIRST ANNUAL REPORTS OF THE EPA IFYGL (INTERNATIONAL FIELD YEAR FOR THE GREAT LAKES) PROJECTS

National Environmental Research
Center

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The field data collection phase of an intensive multidisciplinary study of Lake Ontario was conducted in 1972-73 by agencies of the United States and Canada. The scientific program was designed to further the basic scientific knowledge of the Great Lakes, to provide the basis for improved water quality and quantity management, and to comprehend the broad impact of the lake on the environment of the Great Lakes Basin.

The Chemistry-Biology Program had three major objectives--material balance studies, evaluation of the current ecologic status of the lake, and the development of predictive mathematical models. The chemistry program was conducted at the Rochester Field Office of Region II. The biologically related studies were mainly performed through ten grants administered by the Grosse Ile Laboratory. This document ~~is a first attempt to~~ brings together the annual reports prepared by the Grantees. It is hoped that distribution of these annual reports will provide for a more complete analysis of the data collected during (IFYGL). (Thomas-EPA)

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FIRST ANNUAL REPORTS OF THE EPA IFYGL PROJECTS

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U.S. Environmental Protection Agency
Grosse Ile Laboratory
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PREFACE

The U.S. Chemistry-Biology Program in IFYGL

The field data collection phase of an intensive multidisciplinary study of Lake Ontario was conducted in 1972-73 by agencies of the United States and Canada. The scientific program was designed to further the basic scientific knowledge of the Great Lakes, to provide the basis for improved water quality and quantity management, and to comprehend the broad impact of the lake on the environment of the Great Lakes Basin.

The Chemistry-Biology Program had three major objectives--material balance studies, evaluation of the current ecologic status of the lake, and the development of predictive mathematical models. The chemistry program was conducted at the Rochester Field Office of Region II. The biologically related studies were mainly performed through ten grants administered by the Grosse Ile Laboratory. This document is a first attempt to bring together the annual reports prepared by the Grantees. It is hoped that distribution of these annual reports will provide for a more complete analysis of the data collected during IFYGL.

Nelson A. Thomas
U.S. Co-Chairman
Biology-Chemistry Panel

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OCCURRENCE AND TRANSPORT OF NUTRIENTS AND HAZARDOUS POLLUTING SUBSTANCES

GRANT NUMBER: 800496

Progress Report

April 1972 - August 1973

Environmental Quality Research Unit
New York State Department of Environmental Conservation
Albany, New York

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INTRODUCTION

The central objective of the International Field Year for the Great Lakes (IFYGL) is the development of a sound scientific basis for water resource management on the Great Lakes as an aid in solving problems of water quality and quantity(1). In order to understand the mass and energy transport into, within and out of Lake Ontario, a major portion of the study must be the determination and quantification of the significant input sources, such as air and water-borne material.

Since the bulk of mass inputs to Lake Ontario is likely to be water-borne, a watershed study which includes rates of contaminant discharge originating within an area and the transport, decay and storage of the contaminant through the watercourse appears to be in order.

The transport and decay of the traditional polluting substances (BOD, MPN, etc.) within streams is fairly well understood so that such materials do not need extensive study. However, modern society also disposes of nutrient material and a great variety of synthetic, hazardous materials whose fate in nature is poorly known. Many industrial inorganic chemicals such as sulfides, cyanides, fluorides, heavy and noble metal, and organic chemicals such as solvents, dyes and peroxides present public health, ecological and economic problems after discharge. Within the agricultural sector, many chemicals are broadcast over wide areas and enter watercourses via runoff, percolation, rainfall and dustfall. Both inorganic and organic biocides are presently in use and include such substances as lead arsenate, parathion, chlorinated hydrocarbons and insect hormones.

PROJECT OBJECTIVES

The goals of this project are the determination of the rates of discharge of selected hazardous polluting substances and nutrients in selected drainage basins and the determination of the rates of transport, storage and decay of the substances within the streams in the study area. If successful, this study could provide a tool for predicting changes in lake inputs with changing land use patterns.

OVERALL PROJECT PLAN

The first part of this study was the determination of the general background conditions in the study area. These conditions are being measured by a water quality network of 10 sampling sites located in unpolluted reaches of streams which have different predominant land uses. Both water and sediment samples are being taken. The sampling program consists of 15 water analyses per station every two weeks for 18 months and 5 sediment analyses per station once every 4 months for 16 months. In addition to phosphorus and nitrogen, attention is being given to toxic metals, pesticides and other exotic pollutants.

To supplement the water quality data, flow, land use and climatological information is being collected. By combining the concentration and flow data, fluxes for the various materials can be estimated. In this way, the relative magnitudes of the yields will be estimated and a detailed mapping of the seasonal variations by sub-areas made.

An attempt will be made to correlate the estimated rates of discharge of hazardous agricultural chemicals and nutrients from given land uses to rainfall, runoff, soil type and known application rates.

Supplementing analyses being made as part of this project, an aliquot of the samples collected as part of the water quality network is being shipped to the University of Wisconsin for use in the IFYGL project entitled, "Algal Nutrient Availability and Limitations in Lake Ontario".

In addition to the operation of a general water quality network a point source sampling network has been established to facilitate the development of transport data for hazardous substances and nutrients. Three streams are being intensively studied immediately upstream, downstream every half mile for several miles, and at the outfall of treatment plants to determine rates of mass transport, storage and decay in the system. Each point is being sampled bi-weekly for 5 months. There will also be an intensive sampling period of 5 continuous days on each stream. Additional stations will be sampled during this period so that certain inputs to the streams (particularly field drains and tributaries that are not monitored on the normal bi-weekly trips) may be adequately checked. The sampling program consists of 13 water analyses per station and 4 sediment analyses per station during each sampling period. Plankton and macrophyte samples are also being taken at selected stations along each stream.

SITE SELECTION

Genesee River Basin

After consideration of watersheds available, it was determined that the Genesee River Basin had the most desirable characteristics for meeting the project objectives.

The Genesee River drains some 2,384 sq. miles in Central New York and another 96 sq. miles in North-Central Pennsylvania (Figure 1). The watershed is roughly rectangular in shape, running north-south, and is about 100 miles long and 40 miles wide. The river flows north from Pennsylvania through New York to Lake Ontario. In its course, it intersects the Barge Canal just south of Rochester and continues on through the city. The Genesee River discharge averages about 2,726 cfs near Rochester, and the river flow is carefully regulated by a series of dams in and near the city. Three substantial tributaries enter the Genesee River just upstream of Rochester: Black Creek (mean discharge 101 cfs), Oatka Creek (mean discharge 195 cfs), and Honeoye Creek (165 cfs).

The basin has a humid climate with cold winters and mild summers. The average yearly temperature in the lower basin is 50°F. In the higher elevations the average is 44°F. Average annual precipitation is 34 inches, decreasing from a high of 42 in. in the upper basin to 28 in. in the lower basin. The entire watershed is subject to local cloudburst-type storms(1).

A summertime deficiency of rainfall often occurs in the Genesee Basin. The deficiency extends through the upper four inches of soil as a regular occurrence during part of the summer(2).

A wide variety of soil types and geochemical areas exist as one moves from the mouth of the basin at Lake Ontario up to the upland areas in Pennsylvania.

Topographically, the Genesee River Basin consists of three terraces separated by northward-facing escarpments(1) (Figure II). The southernmost terrace is the Allegheny Plateau whose northernmost edge is the Portage Escarpment which cuts across the basin north of Mt. Morris on an east-west line. The soils in this area are siltstone, shale and sandstone mixed on glacial till with moderate-to-somewhat-poor drainage qualities(3).

Between the Portage Escarpment on the south and the Niagara Escarpment in Rochester on the north, lies the Erie and Huron Plains area. This area has a rolling surface with long, gradual slopes except along the tributary streams which lie in deep ravines. Here the soils are predominately limestone with shale and sandstone, on glacial till with good to moderately good drainage. There is clay concentrated in the subsoil.

The narrow lake plain within the City of Rochester, north of the Niagara Escarpment, consists of lacustrine silt and clay deposits. These soils are imperfectly to poorly drained.

A wide array of land use activities are represented in the basin as shown in Table I.

The largest concentration of urban and residential area is in the Rochester Metropolitan area where the population grew from 615,044 in 1950 to 882,667 in 1970. All of this growth has occurred in the suburban areas since the central city population in 1950 was 332,488 and fell to 296,233 in 1970. This population is concentrated along the main stem of the Genesee River and near Lake Ontario. Rochester itself is heavily industrialized. The area is served by the Barge Canal, 5 railroads, 5 major highways (including the New York State Thruway) and 3 airlines. The Barge Canal, in particular, is still used to move bulky goods like oil, petroleum products, fertilizer and scrap.

The Basin north of suburban Rochester is for the most part sparsely populated and consists of primarily agricultural lands with some forested areas. Although the agriculture is predominantly dairy, there are extensive truck and row crop areas with a prevalence of vegetable crops and fruit orchards. Corn is the major crop. Oats, wheat and barley combined occupy about the same acreage as corn.

New York State has maintained 8 water sampling stations in the Genesee River Basin and has collected historical water quality data, and the U. S. Geological Survey has maintained stream gages on the river since 1935 and on its tributaries since 1945.

The State District Health and Environmental Conservation offices are located in the Genesee Basin and have personnel familiar with the area. An Environmental Protection Agency sampling station for the materials balance aspect of IFYGL is also located at the mouth of this watershed and will provide a connecting line between the two studies.

Specific Site Slection

Water Quality Network

Sub-watershed areas with various single major land use in the Genesee Basin were chosen by using the LUNR area data land use maps. The New York State LUNR program(3) is a detailed inventory of land use and natural resources of New York State. A field survey was then made to check any changes in land use that may have occurred since the land use photos were taken in 1968. The streams in each of the subwatersheds were visited. Each stream had to be large enough to have some flow during periods of dry weather and had to be accessible all year round. The final areas chosen were: (Fig. 1 through 7)

Cropland - Spring Creek (North of Byron)
Pasture - Jaycox Creek (North of Geneseo)
Brushland - East Valley Creek (North of Andover)
Forest - Briggs Gully (East of Honeoye Lake)
High Density Residential - Dansville
Urban - Allens Creek (East of Rochester)

Table II summarizes the flows, areas, and percent of various land uses in each subwatershed.

Station 501 (Cropland) is located on Spring Creek (Fig. 2), north of Byron at the bridge on Route 237. There are 21 dairy farms with a total of 1280 cows and 630 heifers in this area and 2 pig farms. Approximately 54% of the cropland is in corn, oats, wheat and barley.

In the Urban area (Station 502) (Fig. 3), there are 26 active farms, including one dairy farm and 4 horse farms, a total of 29 parks, golf courses and recreational facilities, 21 schools, 13 churches, 1 prison, 1 sewage treatment plant and 30 apartment buildings. Storm and sanitary sewers are separate with the storm sewers all draining into Allens Creek or its tributaries. From May through October, steel siphons (2-10" and 1-8") drain water from the Barge Canal into Allens Creek. The sampling point is located at the U. S. Geological Survey gaging station at the Allens Creek Sewage Treatment Plant, upstream of the plant outfall.

The pasture area (Station 504)(Fig. 4) at Jaycox Creek is a summer pasture for horses and cows. Samples are taken at 2 branches of the Creek (Stations 503 and 505), upstream of the pasture area to monitor the parameter levels of the inflow to the pasture area. Station 504 is located at the bridge on Nations Road. Station 503 is located north of Geneseo, where the northern branch of Jaycox Creek crosses Route 39. Station 505 is located on the Lima Road, where the southern branch of Jaycox Creek crosses the road.

May 1, 1973, we began sampling a small area (Station 512) further downstream from the regular pasture area. This subdrainage basin begins at Station 504 and covers a small cow pasture area. Since Station 512 is inaccessible during bad weather, samples will be taken here from May 1, 1973 through November 15. There are no laboratory results available at this time for this Station.

The area draining the forest watershed (Fig. 5) is sampled at Briggs Gully by the bridge on East Lake Road. Gaging of this stream is extremely difficult due to the large amount of gravel washed down the gully above the sampling point during the flood of June 1973. Most of the flow was underneath the gravel until the stream bed was dozed out September 21, 1972.

At Dansville (Fig. 6), a sample is taken upstream of the high density residential area (Station 508), and a second sample at the downstream end of town (Station 507). The stream flows through residential yards in the center of town and is routed under the streets. The banks are perpendicular and lined with concrete in some sections and steel in other places. In the park (an area 1 block square) where Station 507 is located, the banks are mud and grass. The banks are about 5 feet high all through the town.

The brushland area (Station 509) is drained by East Valley Creek north of Andover (Fig. 7). The sampling site is by the bridge at the first stream crossing on East Valley Road, north of Andover. This area was predominantly agricultural, but the farms are gradually being abandoned. There are a few cattle in some areas along the creek. The main crop is hay, with a minimal amount of oats and corn still being grown in the area. Normally, no fertilizers are used on these farms.

Point Source Network

Three drainage basins have been selected for studying the effect of point source discharges on a stream system. Each of these basins is characterized by primarily agricultural land use and one or two small population centers. Each basin has within it a wastewater treatment facility whose effluent discharge represents a significant (greater than 10 percent) portion of the stream flow draining the basin. On each system samples are taken of the wastewater discharge and one stream sample upstream of the wastewater discharge and several downstream samples at approximate one-half mile intervals. Sediment samples are also taken at each stream sample station.

Fish Creek, in the Towns of East Bloomfield and Victor, New York (Figure 8) drains an area of approximately 14 square miles along a stream reach of about 8.5 miles. The land use within the basin is essentially all agricultural with a few cattle and horse farms. Three tributaries along the reach of the stream contribute about one-half the total stream flow. There are no marshes or swamps along the creek and very few wooded areas. Most of the land in the basin has been cleared and is either in active use or lying fallow.

The creek receives the treated wastewater from the combined Holcomb-East Bloomfield Sewer District. The treatment facility includes primary sedimentation, high rate trickling filtration, rapid sand filtration and chlorination. The average flow is approximately 100,000 gallons per day, 10 percent of which is a pretreated (with Cl_2) cyanide waste from a metal products manufacturing firm

Along the reach of the stream there are 11 regularly sampled stations plus the wastewater discharge. There are an additional 11 stations that represent tributaries and areas of difficult access that are sampled on an irregular basis.

Spring Brook, in the Town of Lima, New York (Fig. 9) drains an area of approximately 33 square miles while the reach of the stream being sampled is about 4.5 miles. The land use of the area of the basin to the south of the Town of Lima is essentially all related to agricultural use, though there are some large swamp and marsh areas. North of the Town of Lima the land use continues to have a predominant agricultural character. There are two small tributaries within the reach of the stream that is sampled. These tributaries represent about 15 percent of the total stream flow.

The brook receives treated wastewater from the Town of Lima wastewater treatment facilities. The treatment process includes primary sedimentation, high rate trickling filtration and stabilization in an oxidation pond. The average flow of the treatment plant is about 100,000 gallons per day.

There are a total of seven regularly sampled stream stations plus the wastewater discharge. There are an additional four occasionally sampled stations that are related to the tributaries.

Avon Creek, in the Town of Avon, New York (Fig. 10), drains a basin of 3.5 square miles along a reach of 3.3 miles. The land use within the basin is all of an agricultural nature with the major portion of the land area devoted to crop production and some land used for grazing dairy cattle. Along its reach the creek flows through two small lowland marshes for about one-quarter mile each, about one-half mile of wooded area and one small impoundment about 100 yards long. The remainder of the land is open and under active agricultural use. There are two significant tributaries that contribute about 40 percent of the stream flow.

The creek receives the treated wastewater from a 350 unit trailer park. The sewage is treated via a contact stabilization system with the effluent applied to slow sand filters the underdrains from which discharge directly to Avon Creek. The average flow is about 45,000 gallons per day.

There are a total of nine regularly sampled stations along the reach of the steam plus the wastewater discharge. There are an additional four occasionally sampled stations related to tributary flow.

FIELD AND LABORATORY METHODS

General

All stream samples collected are being analyzed for pH, total organic carbon, ammonia nitrogen, organic nitrogen, nitrate, nitrite, particulate phosphorus, soluble phosphorus, orthophosphate, chloride, magnesium, calcium, and iron. In addition, the samples from the land use stations are analyzed for sodium, potassium, reactive silica and sulfates. The point source stream samples are also analyzed for aluminum. Additional water samples are being collected 6 times during the study period for pesticide screening and for the analysis of mercury, cadmium, zinc, lead, copper, nickel, manganese, chromium and fluorides.

Sediments from Stations 501 thru 513 are being collected six times and sediments from the remaining stations are collected during each sampling trip. The sediments are analyzed for phosphorus, iron, magnesium, aluminum and calcium.

Cloud cover, air temperature and stream temperature are noted and recorded at each station at the time of sample collection.

The Division of Laboratories and Research, New York State Department of Health, is providing the necessary laboratory services for the water sample analyses. The State Geological Survey, State Science Service of the State Education Department is doing the sediment analyses and providing technical advice on geochemistry.

The U. S. Geological Survey gages the streams at Stations 501, 502, 504, 506, 507, and 509 at the time of sample collection.

Sample Collection and Storage

Water Samples

A two gallon sample of water is collected from 1 to 2 inches below the stream surface near the center of the stream in a container well rinsed with the stream water at the site. At Stations 501, 502, 504, 506, 507, and 509, one gallon of well mixed sample is poured into quart Cubitainers, chilled, and sent to the University of Wisconsin in insulated containers. Two 120 ml polyethylene bottles are filled with well mixed unfiltered samples, for silica and sulfate analyses.

A 47 mm diameter, .45 μ membrane filter in a filtering apparatus is covered with Celite by filtering 4 ml of a Celite suspension (10 g/l distilled water) and discarding the filtrate. Then 300 ml of well mixed sample is filtered and the filtrate distributed into a 120 ml polyethylene bottle for orthophosphate and soluble phosphorus, into a screw-cap tube for soluble carbon analysis, and the rest into a 500 ml bottle. Ten ml of distilled water from a syringe equipped with a narrow gage needle is used to flush the residue from the filter into a screw-cap tube for determination of particulate phosphorus.

A second 300 ml of sample is filtered the same as above. The filtrate is flushed into a screw-cap tube for particulate carbon analysis. The filtrate is poured into the partially filled 500 ml bottle for ammonia, nitrate, nitrite, organic nitrogen, and chloride analyses.

All the above samples are immediately placed in insulated carriers and packed with dry ice for transport to the Division of Laboratories and Research, New York State Department of Health in Albany, where they are stored until analyzed.

Samples for calcium, magnesium, iron, sodium and potassium are prepared by adding 1 ml of concentrated HNO_3 to 100 ml of raw sample.

pH is determined using a Sargent-Welch Model PBL portable pH meter. Then 100 ml of well-mixed sample is titrated for total alkalinity with mineral acid to pH 4.5. Time is allowed for any suspended calcium carbonate to dissolve and for a stable endpoint to be reached.

Sediment Samples

Two methods have been used for collecting sediment samples. The first involves the use of a stainless steel scoop that has a flat bottom, slanted sides and back, and a partial cover. The scoop was designed to have a volume of one quart.

The sediment samples are collected with the scoop and placed in one quart wide mouth containers. The samples are then iced and excess water is decanted after twelve hours.

The second sediment sampling technique involves wet sieving the sediment samples in the field. The method was adopted because the scoop method was not providing a large enough sample of fine (less than 2.00 mm) grained material. The technique involves sieving the samples for two size fractions; less than 2.00 mm but greater than 250 microns and less than 250 microns. The fraction less than 250 microns is retained on a percale cloth with more than 186 threads per inch. The excess water is then drained from each fraction and the fraction is stored on ice in a small plastic bag.

Analytical Methods

Water Samples

Aside from the field measurements described here, all analytical methods are carried out by the Environmental Health Center, Division of Laboratories and Research, New York State Department of Health. A detailed description of methods utilized is given in Appendix A.

Sediment Samples

The sediment samples after collection are subjected to one of two analysis flow schemes shown in Figure 11. Several samples are sent to the New York State Geological Survey for analysis of metals and minerology. These samples are frozen immediately after collection and split in the frozen state to provide equivalent samples for metal and minerology analysis and nutrient analysis. Those samples not split for metal and minerology are subjected to nutrient analysis only.

The samples for chemical analysis are dried at 60°C for 24 hours and then analyzed for total and organic phosphorus with approximately 25 percent of the samples further analyzed for iron, manganese, calcium and aluminum bound phosphorus.

TIME AND COST ANALYSES

The original cost estimate and time schedule is represented by the solid lines in Figure 12. The dotted lines represent the deviation from the estimate. The total Federal costs will be $108,105 as outlined in the grant for 1973-74. The final report date will be June, 1974. The State costs for the first year of this project were $24,955. For the 1973-74 fiscal year, the projected State costs will be $53,145.

PROGRESS TO DATE

Historical Review

A literature search has been conducted for available technical information relating to the study. Industrial and municipal discharge data have been accumulated from the records of the Department of Environmental Conservation. Computer printouts of water quality data amassed by the Department of Environmental Conservation have been collected for all stations in the Genesee River Drainage Basin. Climatological data, soils information, land uses, and other pertinent data have been collected.

Partial Sampling Results

Appendix B contains a computer printout of all the raw data analyzed to this date. No detailed analysis of the data has been made.

Problems

The flood of June 1972 changed the sampling schedule considerably. Gravel and sediments filled in several of the stream beds in the sampling areas. During the summer and fall of 1972, these stream beds were cleaned out and restored as closely as possible to their former state by dozing.

Considerable problems with the analytical methods for phosphorus were encountered. The interlaboratory comparisons were responsible for changing the methods of analyzing phosphorus.

Due to the results of the interlaboratory comparison, our method of analyzing phosphorus was changed as of January 1, 1973. Our sampling will continue until December 31, 1973, so there will be one complete year of data using the same analytical technique. The State of New York will provide any additional funding required for this sampling.

FUTURE PLANS

Field Work

The stream quality network sampling will continue on a bi-weekly basis through December 31, 1973.

The point source stations will be sampled bi-weekly through October 31, 1973.

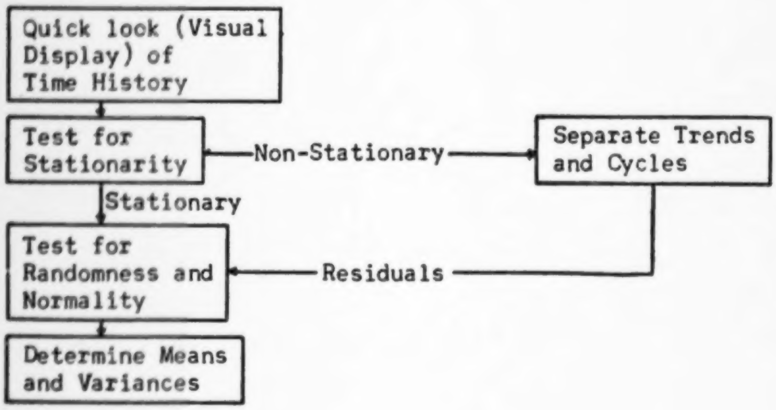
Data Analysis

Literature Data

A review of literature data will be made and reported concentrations and flux rates will be converted to common units and tabulated along with information on the land use, geology and soil type of the drainage area from which they were collected. Conclusions regarding the universality of concentrations and flux rates will be made.

Water Quality Network Data

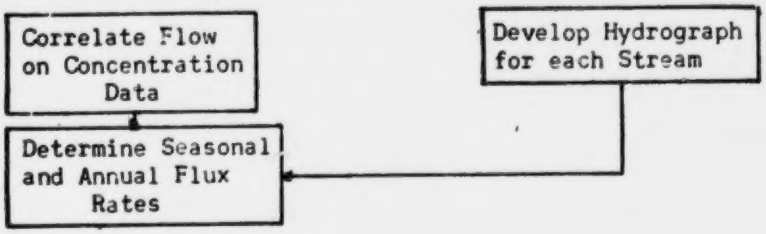
Each parameter collected at each water quality network station will first be treated as a unique record and processed according to the following scheme.*


Quick look (Visual Display) of Time History
Test for Stationarity
Non-Stationary
Separate Trends and Cycles
Stationary
Test for Randomness and Normality
Residuals
Determine Means and Variances

*This is a modification of a procedure suggested in Bendat, J. and Piersal, A., "Measurement and Analyses of Random Data", John Wiley & Son, New York 1966

Conclusions regarding the adequacy of the sample size and sampling period will be drawn from the above analyses. A comparative analysis of the mean concentration with reported literature values will be made.

If the above indicates that an adequate sample is available, the entire set of parameters will be analyzed as follows.


Correlate Flow on Concentration Data
Develop Hydrograph for each Stream
Determine Seasonal and Annual Flux Rates

Conclusions regarding the nature of the chemical-physical system will be inferred from the flow-concentration relationship. Finally, attempts to correlate land type and use parameter and stream sediment type with observed mean concentrations and loadings will be made. The effect of land use on the sample variance will be determined. The results of all of the above will be compared with reported literature values.

Point Source Stream Data

An attempt will be made to model the transport of nutrients below the point sources using the following procedure.

1. Develop a conceptional time series model. Quantize the model as much as possible utilizing reported literature values for rate coefficients and the information from the water quality network station for background.
2. Force fit the model to the data collected during the intensive sampling period.
3. Check to see if the model verifies using the biweekly sampling data.

TABLE I

GENESEE BASIN LAND USE

Land Use(4)	Square Miles(5)		%	
Urban, Commercial, Industrial	99.7		4	
Residential		52.5		2
Commercial and Industrial		15.3		1
Transportation		8.9		1
Extractive		23.0		1
Agriculture	1017.8		43	
Row & close grown crops		46.8		2
Pasture & Meadows		969.3		41
Orchards & vineyards		1.7		1
Forested Land	1125.5		47	
Recreation Land	33.5		1	
No Major Use	88.7		4	
Water		25.0		1
Wetlands		63.1		3
Barren Lands		.6		1
Miscellaneous	18.8		1	
Public Land		14.0		1
Urban Inactive & Construction		4.8		1
	2384		100	

LAND USE AND SUBDRAINAGE BASIN AREAS

Station No.	501	502	503 & 505	504	506	507	508	509
Major Land Use	Cropland	Urban	Beginning Pasture	Pasture	Forest	High Density Residential	Beginning of High Density Residential	Brushland
Area (Acres)	13,824	17,920	7,710	1,314	4,243	142	780	4,666
Land Use (%)								
Cropland	57	23			1		49	30
*High Intensity Agri.	16							
**Brushland	8	19			22			53
Forage Crop			70					
Pasture	6		20	95				
Bogs & Wooded Wetlands	6		10		6			
Forest	6			5	71		45	16
Misc.	1	4					6	1
Urban (residential, public outdoor recreation, commercial)		52				6		
***High Density Residential						94		
Industrial		2						
Average cfs for 1st 9 months of study	26.5	36.4		8.7	11.2	2.15		8.79

* intense production of vegetables, berries, potatoes and other truck crops.
** brush cover up to fully stocked poles less than 30'
*** 50' frontage or less per residential lot.

TABLE II

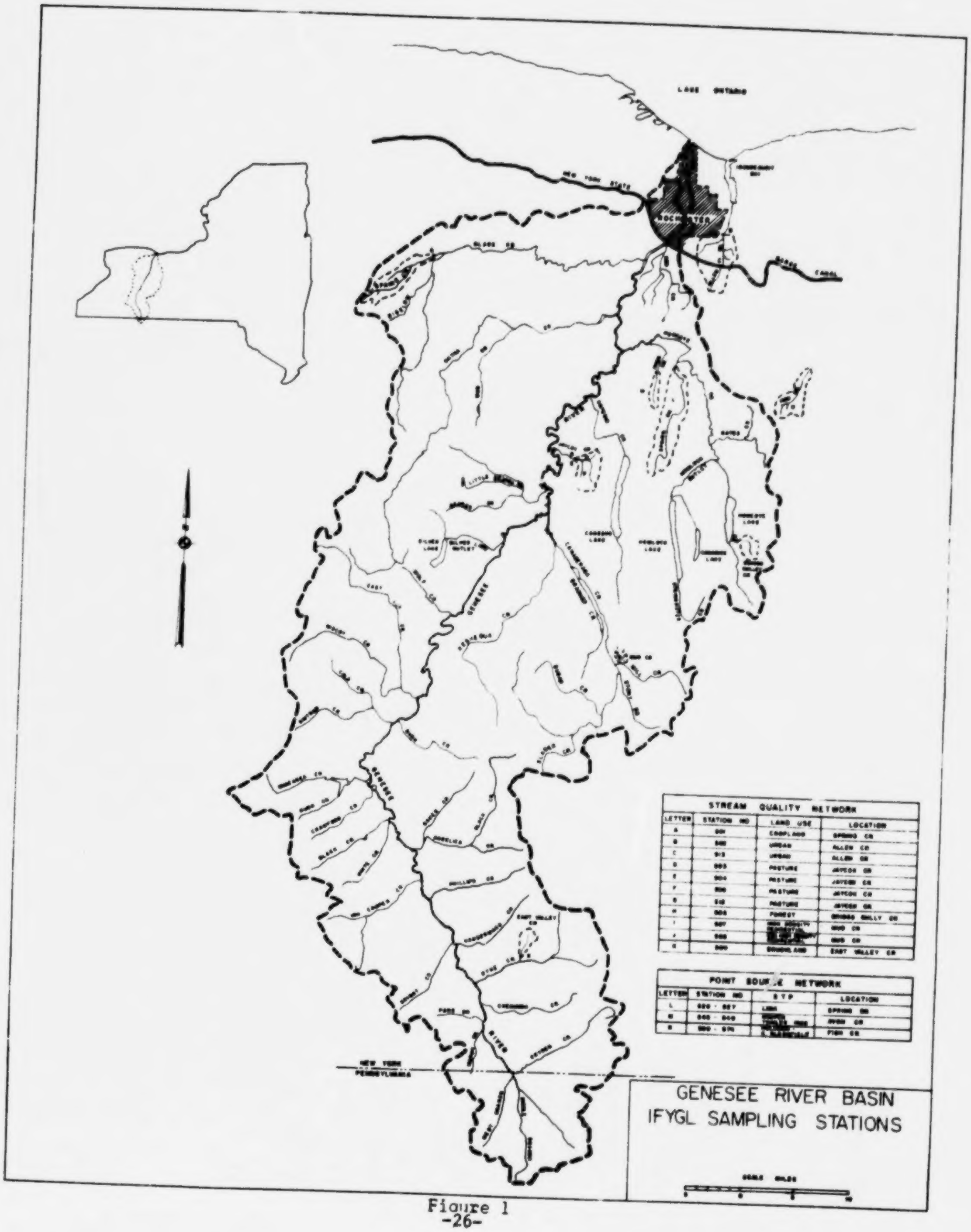

LAKE ONTARIO
NEW YORK STATE
ROCHESTER
BARGE CANAL
GENESEE
LITTLE
CONESUS LAKE
HEMLOCK LAKE
CANADICE LAKE
HONEOYE LAKE
SILVER LAKE
EAST VALLEY CR
NEW YORK
PENNSYLVANIA
STREAM QUALITY NETWORK
LETTER
STATION NO
LAND USE
LOCATION
CROPLAND
URBAN
PASTURE
FOREST
SPRING CR
ALLEN CR
JAYCOX CR
BRIGGS GULLY CR
MUD CR
EAST VALLEY CR
POINT SOURCE NETWORK
STP
FISH CR
GENESEE RIVER BASIN
IFYGL SAMPLING STATIONS
SCALE MILES

Figure 1

OCCURRENCE AND TRANSPORT OF NUTRIENTS AND HAZARDOUS POLLUTING SUBSTANCES

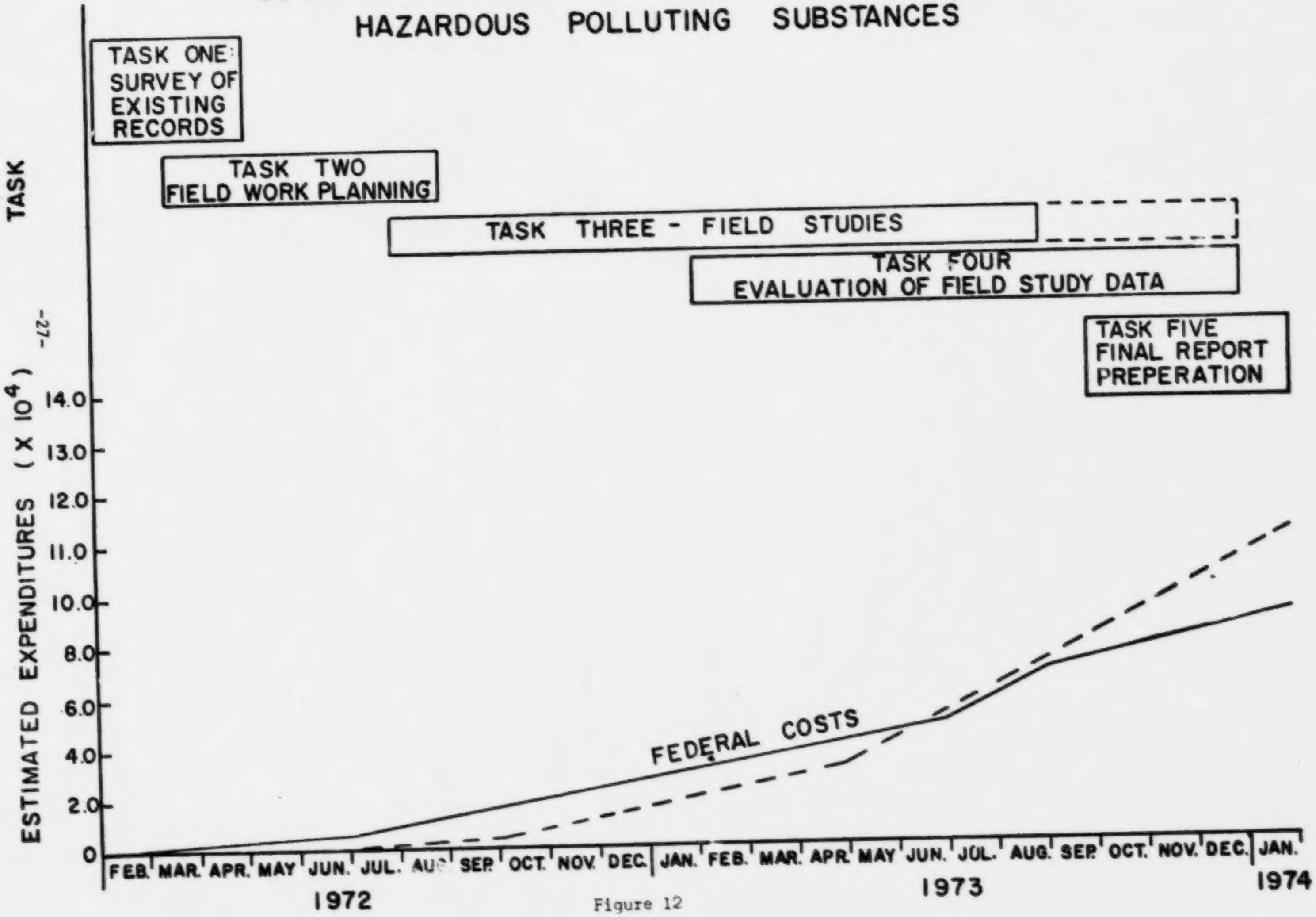


Figure 12

SEDIMENT SAMPLE ANALYSIS FLOW SCHEME

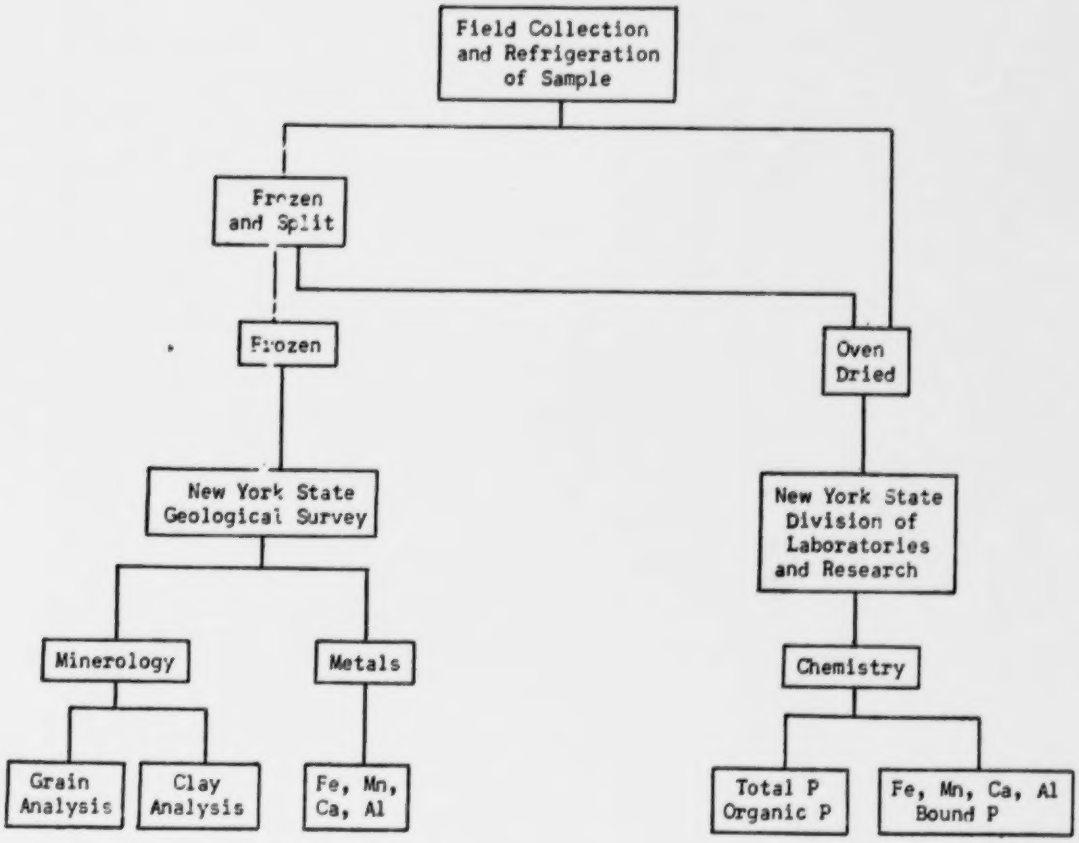

Field Collection and Refrigeration of Sample
Frozen and Split
Frozen
Oven Dried
New York State Geological Survey
New York State Division of Laboratories and Research
Minerology
Metals
Chemistry
Grain Analysis
Clay Analysis
Fe, Mn, Ca, Al
Total P Organic P
Fe, Mn, Ca, Al Bound P

Figure 3

Zooplankton Production in Lake Ontario as Influenced by Environmental Perturbations

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Yearly report (year I, April 1972-March 1973) based upon research supported by Environmental Protection Agency (Grant 800536 to D. McNaught, S.U.N.Y. Res. Found. 20-5003-A).

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Historical (1939-72) Appendix

Review of Subject

Long-term changes in water quality in the Great Lakes have resulted, in part, from accumulated inputs of materials either stimulatory or inhibitory to the primary producers. Changes first observed in primary production have later been observed in zooplankton and fish production. Most important, when aquatic systems have been perturbed for long periods dramatic changes in community structure may make attempts at reversing cultural eutrophication difficult, if not impossible. Thus an initial purpose of the efforts described here was (1) the interpretation of ecological changes in zooplankton populations using indices based upon the concepts of diversity and niche structure. Likewise, we wanted to (2) measure the production of zooplankton communities in Lake Ontario, using both traditional and acoustical collection techniques. Within the team approach designed within IFYGL, we proposed (3) to understand the functioning of natural and disturbed zooplankton communities. Finally we agreed to (4) participate in a broadscale approach to modeling the Lake Ontario ecosystem, under the primary direction of the modeling group from Hydroscience.

The first object, the interpretation of long term changes in zooplankton populations in Lake Ontario, has been in part accomplished with the submission of our report "Changes in zooplankton populations in Lake Ontario (1939-1972)," for publication (appendix).

The second objective, to measure the production of zooplankton communities in Lake Ontario, is partially completed. Acoustical techniques have been developed for measuring the biomass of zooplankton in specific size-classes, the hardware constructed, measurements made on the IFYGL Biological-Chemical cruises, the system calibrated, and a system for reduction of data developed (Sectionpg5). The acoustical data will be processed within the next few months, while the biological data will require many months more work.

Improved understanding of perturbed zooplankton communities will come when the biotic components of the Lake Ontario ecosystem are described and their standing crops and/or productivities estimated. This phase must await the completion of related projects, and considerable interaction among principle investigators.

Status of Program

Field work was completed on 15 June 1973. On ten chemical-biological cruises we collected 2494 biological samples and 1195 acoustical profiles (Table 1). Since each acoustical profile contains 100 separate estimates with depth, we have approximately 119,500 acoustical estimates of biomass.

To date many of the biological samples for the May, June, July and August 1972 cruises have been processed. A method for reducing acoustical data has been developed and is described herein.

Table 1. Resume of data collected on zooplankton in IFYGL Biological Program.

Cruise No.	Cruise Inclusive Dates	Zooplankton Samples (at No. stations)	Acoustical Profiles (at No. frequencies)
1	15-19 May 1972	224 (33)	100 (2)
2	12-16 June 1972	399 (60)	50 (3)
3	10-14 July 1972	380 (60)	200 (3)
4	21-25 August 1972	364 (60)	240 (4)
5	30 Oct.-3 Nov. 1972	355 (60)	240 (4)
6	27 Nov.-1 Dec. 1972	244 (60)	no sonar
7	5-9 February 1973	125 (38)	147 (4)
8	24-28 April 1973	132 (46)	no sonar
9	15-19 May 1973	116 (33)	104 (4)
10	11-15 June 1973	155 (49)	154 (5)
		2494	1195

Planned versus Actual Operation

Generally the project has followed the plans presented in the original and renewal proposals. Some deviations are noteworthy. Equipment funds ($4825) originally proposed for sonar development were used to purchase a Wang 600 calculator to reduce data stored on paper-tape describing acoustical returns from zooplankton layers.

Considerably more in-house programming has been handled in Albany than anticipated. Since the onset of the program a part-time programmer has been working to develop data reduction routines, programs for productivity estimates, niche analysis, etc.

Areas of Program behind Schedule

Only one aspect of the program causes concern, that being the time involved in processing biological samples. To expedite processing, I now plan to hire an additional full-time technician on 1 September, 1973. Thus we should complete counting by the termination date of the contract.

SUMMARY OF RESULTS

Development of Sonar

With the demands of large scale data collection and analysis to understand lakewide zooplankton distributions, Mr. Robert Zeh of SUNY at Albany designed a high frequency sonar capable of handling information from weak targets, as characterized by the zooplankton.

Basically his approach was to transmit an exact waveshape and detect the return in a fashion providing a maximum amount of information on the target. The sonar is similar to many others, in that it transmits a periodic tone burst and then listens for the reflected returning waves and measures the elapsed time and amplitude of the returns. However, it has certain basic differences in circuitry because of target characteristics.

The circuitry starts with the oscillator (Fig. 1), which serves a dual function. It provides the reference signal for both the phase-sensitive synchronous demodulator and the transmitted tone burst. The tone burst is precisely clocked, the duration controlled by the pulse generator. It is then amplified and fed to the transducer. The return signal is received by a separate hydrophone. Any series of returning signals which were originated by the same tone burst may be stored and examined. Single series of returning signals can be recorded in 1000 channels of memory on a transient recorder. This type of analysis should lead eventually to an ability to fingerprint return signals, i.e. to identify the components of the scattering layer.

The returning signal is also simultaneously fed into an (inphase and quadrature phase) synchronous demodulator. This provides a DC signal proportional to the amplitude of the returning tone burst and is independent of the phase of the incoming signal. The output of the demodulator is fed to a storage oscilloscope, providing a picture (depth vs time) similar to the typical sonar chart familiar to most investigators. Then the signal from the demodulator is stored in a signal averager, the heart of the system, for we are interested in the average return from typically "clumped" distributions of zooplankton. The average returns, in one percent increments of depth, are printed on a teletype and displayed on an X-Y plotter (Fig. 1). Data on paper-tape from the teletype can then be later processed using a Wang 600 programmable calculator.

Advantages of this acoustical recording system include (a) ease in taking large amounts of data, (b) real-time display of distributions of particles on X-Y plotter, and (c) the ease in processing large amounts of data from paper-tape. Obviously the system is not sensitive to differences in individual species at this time.

Calibration of Sonar

Three basic corrections have been applied to the raw data (as displayed on the X-Y plotter) to convert return signals to relative biomass. These include a correction for the different characteristics of the transducers (normalization), for the relative attenuation of sound (attenuation) and for the beam angle (Table 2). When these have been applied to the raw data we have a plot of biomass within size category for small targets (Fig. 2). Each higher frequency is sensitive to smaller particles; for example, 80kHz is capable of detecting particles larger than 4 mm, whereas the 200kHz transducer adds another size-class down to 2 mm and 500kHz still smaller particles to 0.4 mm.

On June 11, 1973 we visited station 95 in NE Lake Ontario. Complete reduction of data collected at three frequencies (80, 120 and 200kHz) has provided the profile of zooplankton biomass shown in Fig. 2. At a given depth of 2m, many large particles are evident (80kHz), but an approximately equal number of "crustacean" particles down to less than 2 mm are also evident

Fig. 1. Description of acoustical data acquisition system.

Table 2. Correction factors for acoustical returns necessary to equate returns to biomass of zooplankton.

Formula: $\frac{\text{Intensity x normalization x attenuation}}{\text{beam correction}}$

Sample Calculation:

example: 120 KHz at 4 m depth

$\frac{\text{Intensity x 2.34 x 1.55}}{1.51}$

	(Step 1) Frequency Normalization		(Step 2) Attenuation factor (x)			(Step 3) Beam Correction factor (5° angle)(÷)	
Corrections	Zero Correction factor (-)	Bottom Corr. factor (x)	Channel	Equiv. Depth (M)			
80 KHz	.0593	-	4	1.4	1.08	1 m	1.00
			5	1.7	1.12	2 m	1.16
						3 m	1.33
120 KHz	.0853	2.321	6	2.0	1.17	4 m	1.51
			7	2.4	1.24	5 m	1.71
			8	2.7	1.29	6 m	1.92
						7 m	2.13
200 KHz	.0987	2.203	9	3.1	1.37	8 m	2.37
			10	3.4	1.42	9 m	2.61
			11	3.7	1.48	10 m	2.86
			12	4.1	1.55		

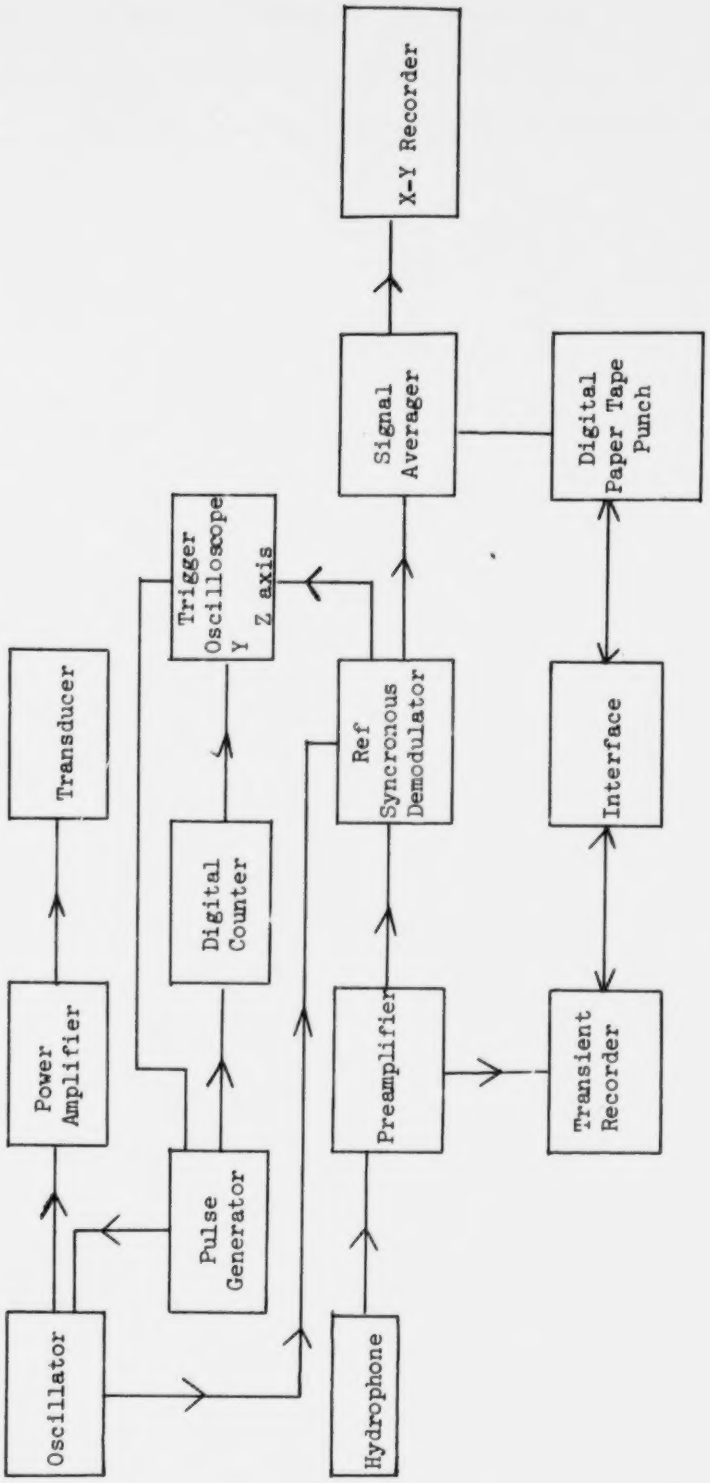
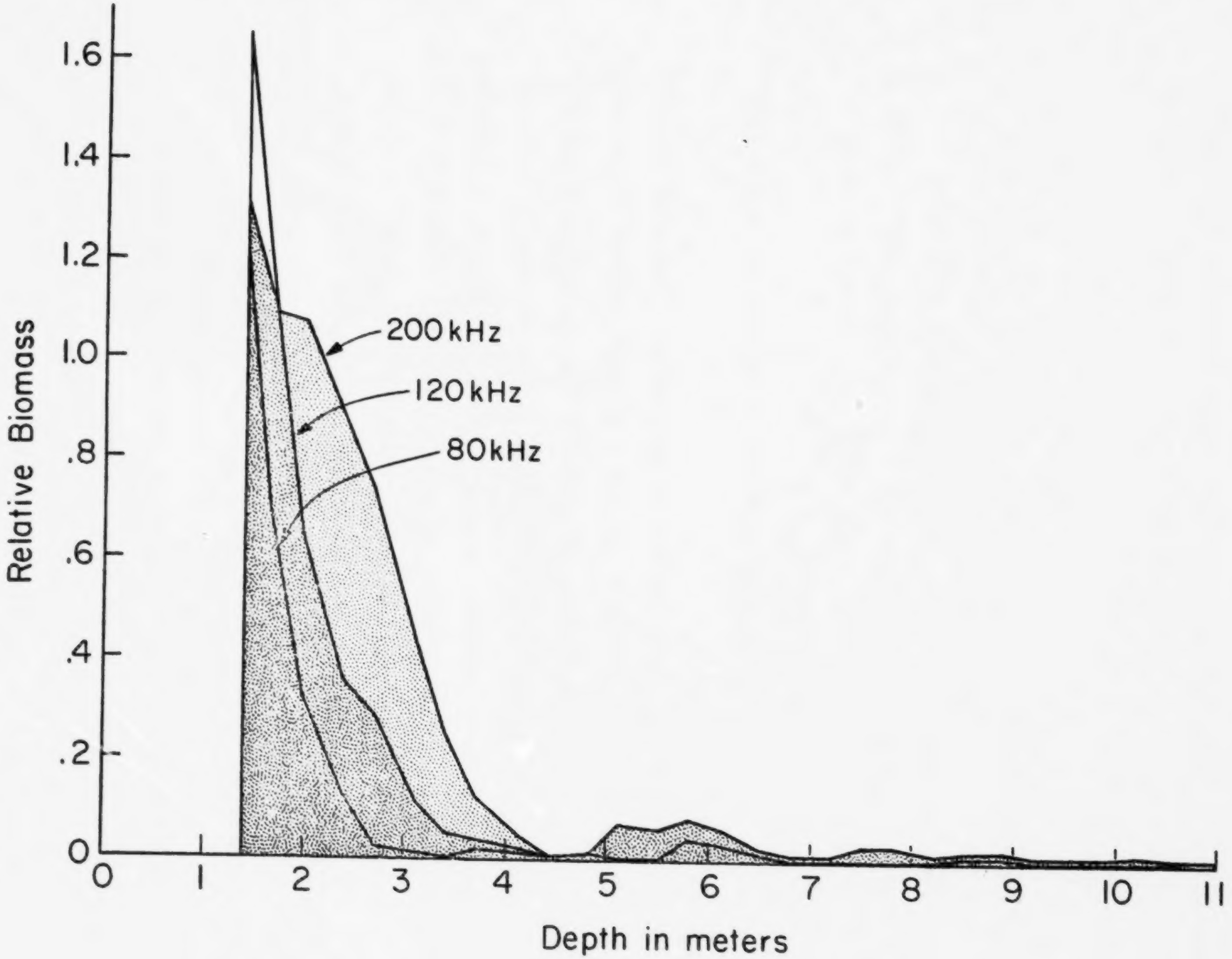

Oscillator
Power Amplifier
Transducer
Pulse Generator
Digital Counter
Trigger
Oscilloscope
Y
Z axis
Hydrophone
Preamplifier
Ref
Syncronous Demodulator
Signal Averager
X-Y Recorder
Transient Recorder
Interface
Digital Paper Tape Punch

Fig. 2. Distribution of biomass within size categories (80kHz = >4 mm, 120kHz = >3 1/2 mm, 200kHz = >2 mm), for station 95 on 11 June 1973. Note abundance of larger organisms near surface.


Relative Biomass
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
0
1
2
3
4
5
6
7
8
9
10
11
Depth in meters
200 kHz
120 kHz
80 kHz

(200kHz). These data were processed manually using the forementioned corrections for beam angle and attenuation. Presently we have approximately 1195 acoustical profiles for Lake Ontario to process automatically using the Wang 600 calculator and teletype interface.

Biological Comparisons

For the use of *other investigators* we have made two tabulations of biological data and a statistical comparison, including the following:

a) a comparison of densities of zooplankton at 0-5m depth at inshore (<50m) versus offshore stations (>50m depth) for the cruises of May, June and July 1972 (Table 3).

b) a comparison of densities of zooplankton for 4 depth intervals for May 1972 (Table 4).

c) a statistical comparison of the inshore-offshore densities (Table 5).

During May, June and July of 1972 the limnetic zooplankton of Lake Ontario were dominated by the copepedites of cyclopoid copepods, *Cyclops bicuspidatus*, and *Bosmina longirostris* (Table 3). The same is true on a yearly basis (see McNaught and Buzzard, Appendix). *Bosmina* is likely a filter feeder preferring small nannoplankton and bacteria. *Cyclops* is likely omnivorous, feeding mainly on copepedites, nauplii and immatures of other organisms, as well as its own.

Many of these limnetic zooplankters are most abundant near the surface (0-5m) in offshore (>50m) waters (Table 4). This is true of *Cyclops bicuspidatus* and *Diaptomus minutus*. However, *Bosmina longirostris* is apparently more abundant inshore, and it is in these waters that its grazing pressure is exerted.

Such comparisons between inshore and offshore populations must have statistical validity, due to the commonly recognized problems of patchiness. It can be demonstrated that *Cyclops* is more abundant offshore, while *Bosmina* exhibits preference for inshore waters, with comparisons made at the 95% level (Table 5).

Table 3. Mean Density of Organisms at 0-5 m. Inshore Stations vs. Offshore Stations for Cruise 1 (May 15-19, 1972), Cruise 2 (June 12-16, 1972) and Cruise 3 (July 10-14, 1972).

Species/Location		May #/m^3	June #/m^3	July #/m^3
Leptodora kinditti				
	In	0	1	2
	Off	0	3	1
Bosmina coregoni				
	In	12	38	61
	Off	10	4	67
Bosmina longirostris				
	In	119	643	13190
	Off	10	133	9355
Daphnia retrocurva				
	In	12	9	116
	Off	3	7	149
Ceriodaphnia lacustris				
	In	0	2	32
	Off	0	1	15
Chydorus sphaericus				
	In	1	6	39
	Off	0	2	4
Cyclopoid copepedites				
	In	183	505	1020
	Off	322	359	1598
Cyclops bicuspidatus				
	In	484	574	13138
	Off	920	1558	7788
Cyclops vernalis				
	In	1	22	73
	Off	1	5	115
Tropocyclops prasinus				
	In	1	6	43
	Off	0	1	10

Species/Location		May #/m^3	June #/m^3	July #/m^3
Mesocyclops edax	In	0	1	0
	Off	0	1	26
Calanoid copepedites	In	22	61	114
	Off	53	54	113
Diaptomus minutus	In	85	45	35
	Off	145	205	75
Diaptomus oregonensis	In	10	6	30
	Off	21	42	18
Diaptomus sicilis	In	11	15	42
	Off	46	46	46
Limnocalanus macrurus	In	162	240	66
	Off	216	182	69
Eurytemora affinis	In	0	16	24
	Off	0	2	1

Table 4. Comparison of species abundance (#/m^3) with depth (meters) for whole lake (WL), inshore (In) and offshore (Off) stations for cruise of May 1972.

Species/Location		0-5 M #/m^3	0-10 M #/m^3	0-25 M #/m^3	0-50 M #/m^3
Leptodora kinditti	WL	0	1	-	-
	In	0	1	0	-
	Off	0	0	0	0
Bosmina coregoni	WL	8	14	6	1
	In	12	27	14	-
	Off	10	1	1	1
Bosmina longirostris	WL	66	70	27	4
	In	119	138	53	-
	Off	10	1	3	4
Daphnia retrocurva	WL	6	6	2	1
	In	12	12	5	-
	Off	3	1	1	1
Ceriodaphnia lacustris	WL	0	1	0	0
	In	0	1	0	-
	Off	0	0	0	0
Chydorus sphaericus	WL	1	1	1	1
	In	10	2	2	-
	Off	0	0	0	1
Cyclopoid copepedites	WL	254	222	161	141
	In	183	310	266	-
	Off	322	133	95	141
Cyclops bicuspidatus	WL	696	520	482	608
	In	484	493	422	-
	Off	980	547	518	608
Cyclops vernalis	WL	1	1	2	1
	In	1	6	4	-
	Off	1	0	0	1
Tropocyclops prasinus	WL	1	1	0	0
	In	1	0	0	-
	Off	0	1	0	0

Species/Location		0-5 M #/m3	0-10 M #/m3	0-25 M #/m3	0-50 M #/m3
Mesocyclops edax	WL	0	0	1	0
	In	0	0	4	-
	Off	0	0	0	0
Calanoid copepedites	WL	37	26	25	30
	In	22	25	24	-
	Off	53	28	26	30
Diaptomus minutus	WL	114	80	73	87
	In	85	72	59	-
	Off	145	89	82	87
Diaptomus oregonensis	WL	15	16	15	11
	In	10	15	15	-
	Off	21	16	14	11
Diaptomus sicilis	WL	28	14	14	15
	In	11	4	10	-
	Off	46	25	17	15
Limnocalanus macrurus	WL	216	138	188.4	206
	In	188	105	239	-
	Off	162	172	157	206
Eurytemora affinis	WL	0	0	0	0
	In	0	0	0	-
	Off	0	0	0	0

Table 5. Significant differences (* = p<.05, NS = not significant) between inshore and offshore populations for cruises of May, June and July 1972.

Species	May (31df)	June (57df)	July (58df)
Cyclops copepedites	1.38 NS	.75 NS	1.32 NS
Cyclops bicuspidatus	1.82 NS	2.15 *	1.52 NS
Cyclops vernalis	.50 NS	2.26 *	.98 NS
Tropocyclops prasinus	1.24 NS	1.75 NS	1.22 NS
Bosmina coregoni	1.27 NS	1.78 NS	.17 NS
Bosmina longirostris	2.75 *	1.46 NS	.86 NS
Ceriodaphnia lacustris	1.11 NS	1.75 NS	1.53 NS
Chydorus sphaericus	1.22 NS	1.57 NS	1.77 NS
Mesocyclops edax	0 NS	.73 NS	1.87 NS
Daphnia retrocurva	2.99 *	.36 NS	.63 NS
Calanoid copepedites	2.87 *	.45 NS	.04 NS
Diaptomus minutus	1.67 NS	3.61 *	1.61 NS
Diaptomus oregonensis	1.18 NS	1.49 NS	1.00 NS
Diaptomus sicilis	2.83 *	1.42 NS	.18 NS
Limnocalanus macrurus	.81 NS	.38 NS	.15 NS

Impact of Large Cities on Community Structure of Zooplankton in Lake Ontario

Water quality and the abiotic factors which influence the biota of Lake Ontario are of prime interest in the IFYGL program. Initially we proposed to subject our processed data to an analysis, using niche theory to derive indices which would detect changes in community structure. The data on zooplankton (species and abundance) for June and July 1972 have now been subjected to community analysis. A program in Fortran IV was written for the Univac 1108 computer to calculate diversity and various niche parameters.

Niche parameters employed in this comparison include the community competition coefficient (α), the theoretical community carrying capacity (K), the ratio of observed to theoretical carrying capacity (N/K), and diversity (H). Each of these parameters is discussed in the attached manuscript on long-term changes in Lake Ontario (Appendix).

The mean number of zooplankton Crustacea (N), the theoretical carrying-capacity (K) and the N/K ratio do not differ when populations off Toronto, Rochester, Hamilton and Oswego are compared to populations at greater depths around the remainder of the lake (Table 6).

The diversity of planktonic communities off the forementioned large cities is less than one-half that for communities, at the same time and similar depths, but distant from large cities (Table 6). This is rather startling information, since longshore currents in Lake Ontario transport zooplankton past urban areas rather rapidly (0.9 km/hr). In fact, in June 1972 the diversity off large cities was 1.21 as opposed to 3.44 for similar inshore communities away from urban influences. In July a similar comparison showed a diversity of 1.45 off urban areas, as opposed to 3.47 off less inhabited shorelines. These differences in diversity are significant at the 95% level (Table 7).

Such reductions in diversity near cities are due both to a reduction in

Table 6.

Impact of "Big Cities" (Toronto, Rochester, Hamilton, Oswego) on Community Structure of Zooplankton in Lake Ontario.

	Total N (#/m^3)	Alpha (variance)	Total K (#/m^3)	N/K	Diversity (H)
June 1972 "Big Cities"	2073	.517 (.12)	28885	.07	1.21
June 1972 Rest of Lake	2893	.235 (.09)	28887	.10	3.44
July 1972 "Big Cities"	22414	.396 (.12)	185978	.12	1.45
July 1972 Rest of Lake	28962	.241 (.09)	292435	.10	3.47

Table 7.

A statistical comparison of Alpha and other factors between two Cruises in June and July on the Big Cities vs Rest of Lake.

		June 1972	July 1972	t_{05}	df	$p < .05$
Alpha	Cities	.517	.396	3.44	1	NS
	Lake	.235	.240			
N/K	Cities	.07	.12	0.2	1	NS
	Lake	.10	.10			
Diversity	Cities	1.21	1.45	20.2	1	xx signif. $(p < .05)$
	Lake	3.44	3.47			
Total N $\#/m^3$	Cities	2073	22414	1.3	1	NS
	Lake	2893	28962			
Total K $\#/m^3$	Cities	28885	185,978	1.0	1	NS
	Lake	28887	292,435			

the number of species present (richness) and a redistribution of relative numerical dominance (evenness). In June 1972, when the diversity near the cities was 1.21 compared to 3.44 for the rest of the lake, there were 5 less species (14 as opposed to 19) in watermasses adjacent to our four large cities (Table 8). In July there were 7 less species (12 as opposed to 19) in these inshore areas influenced by urban living patterns.

This reduction in richness was attributable to the loss of similar species from "Big City" watermasses in both June and July 1972. In June Daphnia galeata, Ceriodaphnia lacustris, Chydorus sphaericus and Holopedium gibberum were missing from urban watermasses. In July these same cladocerans plus Diaptomus oregonensis were missing. Replacing them and causing a shift in evenness (Table 8) was Cyclops bicuspidatus. We know that Cyclops (Table 3) is dominant in deep open waters (>50m), but when the cladocerans are lost, it moves inshore near cities. The loss of these 4 cladocerans surprised us. Normally the Diaptomids are thought to be most sensitive to environmental perturbation.

It is important to make similar comparisons of nutrients, phytoplankton and fishes at precisely these same "urban" stations. But we feel that we have at present evidence for significant environment perturbation offshore from urban areas adjacent to Lake Ontario.

Table 8. Richness and evenness components of diversity, showing reduced richness in areas of Lake Ontario adjacent to "Big Cities".

Date and Locality		Diversity (H)	Richness	Evenness	Number/m^3 (N)	Number of Species (S)
June 1972	Big Cities	1.21	3.92	1.05	2073	14
	Rest Lake	3.44	5.20	2.69	2893	19
July 1972	Big Cities	1.45	2.52	1.34	22414	12
	Rest Lake	3.47	4.04	2.71	28962	19

Appendix: Changes in Zooplankton Populations in Lake Ontario (1939-1972).

CHANGES IN ZOOPLANKTON POPULATIONS IN LAKE ONTARIO (1939-1972)[1]

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U.S.A.

Revised 20 July 1973

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[1] Contribution -- of the IFYGL Biology-Chemistry Program. Supported by Grant 800536 from the U.S. Environmental Protection Agency.

Abstract

Since 1968 the crustacean limnoplankton of Lake Ontario has been dominated in July by Cyclops biscuspidatus and Bosmina longirostris. Apparently in 1939 Daphnia spp. and Diaptomus spp. were relatively more abundant at the same time. Generally summer standing crops of zooplankton in the inshore waters (<50m) do not show significant increase from 1939 to 1972. At the same time the composition of these communities has shifted from dominance by the cyclopoids and calanoids (81%) to the cladocerans (48-84%). Concomitantly numerous new species have been recorded, the most recent being Diaptomus ashlandi in 1972. Two additional trends are evident since 1968. The species diversity has increased in the inshore waters from 1.77 to 2.98, due to increases in the evenness component. At the same time their theoretical carrying-capacity for zooplankton has also increased.

Introduction

Aquatic ecosystems have characteristically been perturbed through either the addition of nutrients stimulatory to phytoplankton production, by substances toxic to such production, or by the addition of new exctic fishes. The crustacean zooplankters in such systems respond, as evidenced by changes in community structure, to changes in food resources and to selective predation. Thus whether aquatic ecosystems are perturbed from the top downward or stimulated from the first trophic level upward, the crustaceans are sensitive integrators of such changes.

It is the purpose of this review to examine suitable available data on zooplankton populations of Lake Ontario to determine whether significant changes in community structure have occurred since 1939. Our first approach will be to examine comparable collections for significant changes in zooplankton density (N) and relative composition at the ordinal (Copepoda and Cladocera) and generic levels. Secondly, for the years 1969-1972, when extensive collections were made, we will utilize niche theory to predict the theoretical carrying capacity (K) of the Lake Ontario ecosystem, the extent to which this capacity is filled (N/K), changes in the diversity of the system (H) and whether these changes involve the influx of new species (richness) or changes in relative abundance (evenness). In making these later comparisons, we will present new species records and information on community structure which we collected during the IFYGL program.

Seven investigations since 1912 provide an insight into changes in zooplankton community structure (Table 1). The collections by Patalas (1969) made in 1967 constitute the first intensive lakewide study, followed by that of Nauwerck *et al.* (1972) in 1970 and our current IFYGL study which commenced in May 1972. In addition, Whipple (1913) made a single useful collection at the mouth of the Genesee River in 1912 and Tressler et al. (1940) made a limited collection in the same area in 1939. Anderson and Clayton (1958) did not make extensive collections, but discovered a new genus, Eurytemora, previously not observed in the Great Lakes. McNaught and Fenlon (1972) took limited inshore samples in 1969 and 1970 in the Oswego area.

Differences in collecting gear make comparisons of zooplankton abundance difficult. Patalas (1969) used a net with a mesh aperture of 77 μ and Nauwerck et al. a similar net of 64 μ, whereas McNaught and Fenlon (1972) and our current IFYGL study have employed nets of 154 μ aperture. Tressler and Austin (1940) likely used a net with an aperture of 64 μ attached to their Juday trap, whereas Whipple (1913) did not describe his net.

Thus all investigators failed to sample copepod nauplii and copepodites were sampled with differing efficiency. Most conservative comparisons will thus be between numbers of adult forms. However, all nets were capable of sampling Bosmina, a point critical to our conclusions, as evidence by our large catches of this animal in 1969 with a coarse net (McNaught and Fenlon (1972)).

Additional problems arise when we consider the numbers of samples collected. Whipple (1913) took a single sample in August 1913, and Tressler and Austin (1940) a vertical series of eight samples in 1939. With the advent of intensive studies in recent years more information is available. Nauwerck et al. (1972) collected approximately 30 samples on each of 12 cruises in 1970. Currently we are examining 60 stations in the IFYGL program, taking 1-5 vertical hauls at each station.

Theory Used in Comparisons of Community Structure

Two basic assumptions underlie the use of niche theory (Levins, 1968) to predict the maximum theoretical carrying-capacity of an aquatic environment. First we have assumed that crustacean populations exhibit sigmoid growth in nature, and that the concept of an environmental carrying capacity is real for them. Secondly, we have assumed that with community development, a likely evolutionary strategy includes the reduction of interspecific competition, i.e. a reduction of the mean community competition coefficient (α).

Assuming that crustacean populations continually push against an ever changing carrying-capacity, we must first estimate the competition coefficient (Levins, 1968):

$$\alpha_{2\cdot 1} = \frac{\sum_{h=1}^{n} P_{1h} P_{2h}}{\sum_{h=1}^{n} P_{1h}^{2}} \tag{1}$$

where h is an environment and P_1 and P_2 are the proportion of species 1 and species 2. This alpha assumes that competition for resources is proportional to the probability of occurrence in an environment h (Lane and McNaught, 1970). Then, from the logistic:

$$\frac{dN_1}{dt} = r_1 N_1 \left(\frac{K_1 - N_1 - \alpha_{2\cdot 1} N_2}{K_1} \right) \tag{2}$$

where r_1 is the instantaneous growth rate of species 1, we can calculate the maximum theoretical carrying capacity (K_1) for species 1, where:

$$K_1 = N_1 + \sum_{2=1}^{n} \alpha_{2\cdot 1} N_2 \tag{3}$$

This maximum carrying-capacity is the maximum density which a species would obtain if no competitors were present, where the calculation is made with an assumption of steady-state with equation (3) and derived from (2) at $\frac{dN_1}{dt} = 0$.

Finally, Shannon-Weaver species diversity values were determined for inshore and offshore waters for the years 1969-1972, where:

$$(4) \qquad H = - \Sigma p_i \log_e p_i$$

where p_i = proportion of individuals belonging to the ith species.

Changes in Population Density and Composition

Standing-crop data for crustacean zooplankton are available for the inshore waters of Lake Ontario for the month of July in the years 1912, 1939, 1969, 1970 and 1972 (Table 2). For 1912 and 1939 the means are based on one (1) and eight (8) samples respectively, making significant comparison with the 1969-72 densities difficult. Even with these restrictions certain general trends are evident.

The cyclopoid copepod Cyclops bicuspidatus thomasi Forbes and the cladoceran Bosmina longirostris (Deevey) were dominant in July (1969-72) just as they are seasonally (Patalas, 1969; Nauwerck et al., 1972). Tropocyclops prasinus mexicanus (Kiefer), Mesocyclops edax (Forbes), and Cyclops vernalis (Fischer) were the cyclopoids of secondary importance. The calanoids, which are represented by only 0.6-3.0% of the population, are composed of three species of Diaptomus, as well as Eurytemora affinis (Poppe) and Limnocalanus macrurus (Sars). Among the cladocerans we have presented limited evidence for a shift from dominance by Daphnia spp. in

1939 (Tressler and Austin, 1940) to Bosmina spp. some time between 1939 and 1969. Ceriodaphnia lacustris (Birge) and Chydorus sphaericus (Müller) have been of secondary importance. We should also note an apparent decline of Leptodora kindtii (Focke) in 1970 and 1972, possibly due to size-selective predation by fishes.

A basic trend at the ordinal level is evident (Table 2). Copepods dominated these waters in 1939 but had given way by 1969 to the cladocerans (Fig. 1). Let's examine this trend, which cannot be supported by statistics due to the few samples collected in early years. This trend is not likely to be confounded by sampling-gear problems, as Tressler and Nauwerck used comparable fine-mesh nets, whereas McNaught and Fenlon (1972) found even more Bosmina in 1970 with their coarser net. Thus, for the inshore waters of Lake Ontario we have provided evidence that increases in standing crop, for the few years sampled between 1939 and 1972, are associated with increases in the relative proportion of cladocera, with 1969 an exceptionally high year. The cladocerans constituted only 19% of the July population in 1939, as contrasted to 48-84% from 1969 through 1972 (Table 1).

A second trend suggesting a general increase in standing crop between 1939 and 1972 cannot be supported (Table 2). Obviously differences in mesh-size of the nets used cause problems with an equivalent sampling of copepodites (Table 2). Thus we have elected in addition to compare the total numbers of Daphnia spp. for June of 1939 and 1970, as mesh size was the same. The comparison was further restricted to a comparison of the seven samples collected by Tressler off Rochester to three collected by Nauwerck et al. in the same area. The (3) July 1970 samples did not contain Daphnia spp., the pulse of which was apparently delayed until August 1970. However, as shown below, the density of Daphnia spp. in July 1939 was not significantly ($p > 0.3$) different than that in either July or August 1970.

	July '39	July '70	Aug. '70
Mean Density	5900	0	5422
Students t		1.45 (NS)	0.128 (NS)

We must conclude that the extreme variation between the July 1939 samples makes comparison impossible.

New Records for Species in Limnoplankton of Lake Ontario

In 1958 Anderson (1959) discovered the presence of *Eurytemora affinis* (Poppe), a calanoid copepod usually found in brackish waters, in Lake Ontario. Since that time it has been discovered in Lake Erie in 1961 and in Lake Huron in 1965 (Faber and Jermolajev, 1966). Nauwerck *et al.* (1970) added *Alona intermedia* (Sars) and *Macrocyclops albidus* (Jurine) to the Ontario fauna, two rare benthic forms constituting less than 0.02% of the mean annual standing crop.

We have discovered three additional species, one of which is commonly planktonic. *Diaptomus ashlandi* (Marsh) was collected in the shallow NE sector at IFYGL stations 95 and 98 and at station 83 (0-10m) in May 1972. *Macrothrix laticornis* (Jurine) was found in a 30m haul at station 96 and in a 5m haul at station 8 off Toronto in August 1972. *Ilyocryptus spinifer* Herrick was found at station 31 offshore from 30 Mile Point in May 1972. Both of these latter forms are commonly substrate feeders, and may have been taken when our net hit bottom.

Recent Changes in Community Structure

For comparative purposes Lake Ontario has been divided into inshore

(9-50m depth) and offshore (>50m depth) zones. Within these zones we have compared total populations of zooplankton studied from 1967 (Patalas, 1969) through 1972 (current report).

Total crustacean density (N), the community competition coefficient (α), the theoretical community carrying-capacity (K), and the ratio of the observed to theoretical carrying-capacity (N/K) are employed in these comparisons. Each of these theoretical parameters (other than N) was calculated from original values for each station, and not from lumped means by cruise, using a program in Fortran IV written for the Univac 1108 computer.

Inshore: Two trends, including an increase in diversity (H) from 1969 to 1972 and the seasonal pattern of fluctuations in observed: theoretical carrying-capacity, are noteworthy. Changes in yearly abundance (N) are associated with gear selectivity, while the mean yearly community competition coefficient has not changed significantly (Table 2-3).

The diversity of the inshore populations increased from 1.77 bits in 1969 to 2.98 bits in 1972 (Table 3). The 1969 figure is for the Nine Mile Point Area (McNaught and Fenlon, 1972), while the 1970 and 1972 estimates are whole-lake averages. Use of the non-parametric Wilcoxon two-sample statistic indicated a significant difference at the 80% level ($p < 0.2$) between the 1969 and 1970 means, when July data were considered (Table 5). This obvious increase in diversity was not due to the addition of new species (richness) in 1970, but to a change in their relative abundance (evenness), as clearly illustrated in Table 5. The genera Bosmina and Cyclops were relatively more abundant in 1970. An additional increase in diversity occurred in these 2 months in 1972, but it was due to the observation of additional species (richness). This trend must be explored in the future, for if it persists it indicates a change toward increased stability in inshore areas. Usually shallow areas are more productive and less diverse with regard to fauna and flora.

Additionally the theoretical carrying-capacity increased for comparable months (June-July) from 1969 to 1970 (Wilcoxon non-parametric, $p < 0.2$). This change, however, must be treated with caution, since finer mesh nets were employed in 1970, and numerically (N) 1969 was not significantly different than 1970.

The ratio of observed (N) to theoretical maximum (K) carrying-capacity constitutes a new measure of the ability of r-selection animals to push against environmental resistance (Lane and McNaught, 1973). R-selection animals, by definition, have high population growth rates (r). An interesting seasonal pattern has been observed for 1970. The N/K values are highest in the spring (February-April). It is logical to hypothesize that an increase in some available food resources may permit zooplankton populations to operate closer to theoretical carrying capacity in the spring. Traditionally r-selection organisms have been described as filling only a small fraction of their potential carrying-capacity, and this range for 1969 to 1972 is a consistent 6-24% (yearly mean 9-12%) (Table 3).

Offshore: A similar pattern in the N/K ratio for the crustacea was noted for the offshore waters in 1970 (Table 4), with values greater 0.14 from February through mid-July. In these offshore waters the mixing of nutrients from deep waters may prolong the period of apparent stimulation of zooplankton growth, as logically intermediated by increased autotrophic production.

As expected, diversity values are generally higher and more constant for these offshore populations. This would imply a more stable environment than in the inshore areas.

Inshore-Offshore comparisons: Standing crops of crustacean zooplankton were approximately three times as great in inshore waters per unit volume in 1970 than in offshore areas (Tables 3-4). Limited data for 1972 show less difference. Along with differences in diversity, with the inshore waters slightly less diverse in terms of their crustacean populations (2.23 bits vs. 2.56 bits), we have for 1970 the image of a more productive but less stable inshore zooplankton community. We will be able to deny or confirm this observation when the 1972-73 IFYGL data have been processed. These initial trends, preliminary in nature, should suffice to draw our attention to the limited perturbation of these communities today.

Significance

Crustacean abundance has been directly related to the degree of trophy, especially phosphorus loading rates, in the Great Lakes (Patalas, 1972). Lake Ontario is currently considered a morphometrically oligotrophic lake. Its zooplankton populations, dominated to an increasing degree by the Cladocera and Cyclopoida (Table 2), suggest that it is generally more eutrophic than the upper Great Lakes. This is especially true in the case of Lake Superior, which is dominated by Calanoida (Diaptomus sicilis).

Relative to our stated purposes, we have illustrated a shift at the ordinal (Calanoida to Cyclopoida and Cladocera) and generic (Daphnia and Diaptomus to Cyclops and Bosmina) levels for the period 1939-1972. At the same time no significant change was discovered in total density of zooplankton. For the recent period 1969-1972, significant increases in diversity have occurred, due to increases in the evenness component. Concomitant changes in carrying-capacity are questionable due to sampling techniques.

Standing crops of zooplankton, even when they are as different as they

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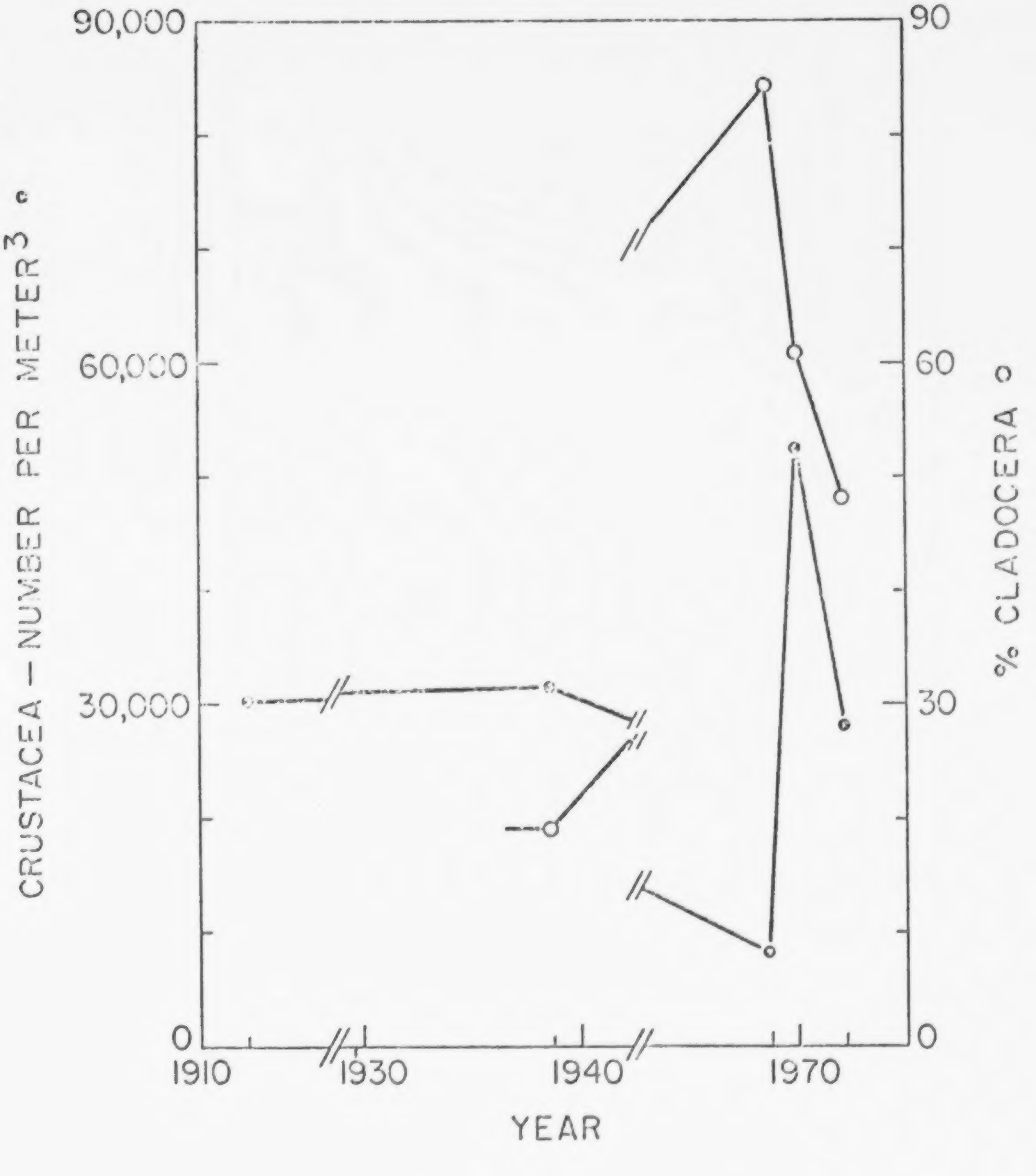
Fig. 1. Changes in mean yearly density (number/m^3) and relative abundance of crustaceans of inshore waters of Lake Ontario (1912-1972).



90,000
60,000
30,000
0
90
60
30
0
CRUSTACEA — NUMBER PER METER^3 ●
% CLADOCERA ○
1910
1930
1940
1970
YEAR

Table 1. Comparison of data sets used to compare zooplankton communities.

Author and Year Published	Inclusive Dates Collection	Gear and Diameter	Mesh Aperture (μ)	Time day/night	Number Samples	Depths	Area
Whipple (1913)	15 August 1912	Cone net	unknown	daytime	1	0-6m	1.6 km off Rochester
Tressler and Austin (1940)	20 July 1939	Juday trap	likely 64 μ	daytime	8	0, 5, 10, 15, 20, 30, 40 and 45m	4.8 km off Rochester
Patalas (1969)	June-Oct. 1967	Wisconsin net, 25 cm	77 μ	day/night	190	0-50m	whole lake
McNaught and Fenlon (1972)	Aug.-Oct. 1969 July-Aug. 1972	Clarke-Bumpus	154 μ	daytime	110	0, 5, 10, 15, 20, 30, 40m	1-8 km off Oswego
Nauwerck *et al.* (1972)	Jan.-Dec. 1970	Cone net, 40 cm	64 u	day/night	360	0-50 m or 0-bottom	whole lake
McNaught and Buzzard (this publ.)	15 May-14 July 1972	Cone net, 80 cm	154 u	day/night	152	0-5m	whole lake

TABLE 2. Zooplankton standing crops for July in inshore waters of Lake Ontario, with the exception of August 1972, in number per meter^3.

Order and species	Source Year of collection	Whipple 1912	Tressler and Austin 1939	McNaught and Fenlon 1969	McNaught and Fenlon 1970	Nauwerck et al. 1970	McNaught and Buzzard 1972
Cyclopoida							
Copepodites				1,061	29,267	+	1,020
Cyclops bicuspidatus			+	15	0	1,191	13,138
Tropocyclops prasinus				0	0	32	43
Mesocyclops edax				0	0	0	26
Cyclops vernalis				17	0	80	73
Total cyclopoida				1,093	29,267	20,000	14,300
Calanoida							
Copepodites						346	114
Diaptomus minutus				215	516	28	35
Diaptomus oregonensis			+			31	30
Diaptomus sicilis							42
Eurytemora affinis				0	0	20	17
Limnocalanus macrurus				38	15	4	66
Total calanoida				253	531	429	274
Total copepoda			25,300	1,346	29,798	20,429	14,574
Cladocera							
Bosmina longirostris				4,423	58,315	31,731	13,190
Bosmina coregoni						24	61
Daphnia retrocurva				302	1,187	249	108
Daphnia longiremis			5,900	–	–		
Daphnia galeata				218	74		
Ceriodaphnia lacustris				95	148	33	32
Chydorus sphaericus				0	220	62	39
Leptodora kindtii				30	38	–	3
Total cladocera			5,900	6,958	59,982	32,099	13,433
Total crustacea		30,000	31,200	8,304	89,780	52,528	28,007
Relative numbers							
% Cyclopoida		–	81.1	13.2	32.6	38.1	51.1
% Calanoida		–		3.0	0.6	0.8	1.0
% Cladocera		–	18.9	83.8	66.8	60.9	47.9

Table 3. Inshore populations, community structure during 1969, 1970 and 1972, including density, competition coefficient, diversity, theoretical maximum carrying capacity and ratio of density:carrying capacity. (N = Nauwerck; M = McNaught and Buzzard; P = Patalas.)

Year	Day Month	Data Source	Total Density Crustacean Zooplankton (N) number/m^3	Community Competition Coefficient (α) with variance ()	Theoretical Carrying Capacity (K) number/m^3	Ratio Observed to Theoretical Carrying-Capacity (N/K)	Diversity (H)
1969	10 July	M	5,197	.50 (.13)	46,857	.11	1.90
	16 July	M	9,350	.56 (.10)	94,164	.10	1.57
	4 August	M	12,623	.48 (.14)	81,174	.12	1.56
	24 August	M	7,821	.33 (.12)	71,486	.11	1.84
	27 August	M	4,542	.36 (.10)	33,796	.13	2.04
	31 October	M	8,917	.32 (.18)	51,626	.17	0.57
	MEAN 1969		8,075	.43	63,184	.12	1.77
1970	3-8 February	N	341	.49 (.08)	2,137	.16	2.29
	3-8 March	N	1,470	.56 (.10)	11,072	.13	1.49
	31 March-4 April	N	1,204	.44 (.11)	5,103	.24	2.50
	28 April-1 May	N	1,894	.35 (.09)	10,753	.18	2.36
	25-29 May	N	5,118	.38 (.22)	71,922	.07	0.99
	22-27 June	N	4,253	.28 (.14)	31,705	.13	2.27
	16-20 July	N	40,485	.28 (.12)	377,948	.11	2.07
	23 July	M	102,426	.34 (.11)	967,581	.12	2.41
	30 July	M	69,750	.33 (.07)	573,704	.12	2.14
	7 August	M	58,870	.36 (.08)	433,160	.14	2.30
	16-20 August	N	34,085	.48 (.10)	277,549	.12	2.57
	14-19 September	N	28,165	.39 (.10)	196,155	.14	2.61
	13-17 October	N	42,761	.52 (.11)	393,426	.11	2.40
	16-20 November	N	7,438	.44 (.08)	66,260	.11	2.63
	7-11 December	N	2,573	.55 (.14)	25,877	.10	2.55
	MEAN 1970		26,722	.41	229,623	.13	2.23
1972	15-19 May	M	1,272	.43 (.15)	9,866	.13	3.00
	12-16 June	M	2,236	.30 (.09)	36,413	.06	2.86
	10-14 July	M	25,665	.27 (.06)	303,778	.08	3.07
	MEAN 1972		9,724	.33	15,426	.09	2.98

Table 4. Offshore populations, community structure during 1968, 1970 and 1972, including density, competition coefficient, diversity, theoretical maximum carrying capacity and ratio of density:carrying-capacity. (N = Nauwerck; M = McNaught and Buzzard; P = Patalas.)

Year	Day Month	Data Source	Total Density Crustacean Zooplankton (N) number/m^3	Community Competition Coefficient (α) with variance ()	Theoretical Carrying Capacity (K) number/m^3	Ratio Observed to Theoretical Carrying-Capacity (N/K)	Diversity (H)
1968	12-13 September	P	28.7	.52 (.14)	509	.06	2.93
1970	3-8 February	N	793	.46 (.09)	4,097	.19	2.59
	3-8 March	N	987	.54 (.10)	5,502	.18	2.56
	31 March-4 April	N	661	.47 (.14)	2,527	.26	2.28
	28 April-1 May	N	1,581	.43 (.09)	6,564	.24	2.70
	25-29 May	N	846	.61 (.13)	6,121	.14	2.44
	22-27 June	N	2,168	.39 (.13)	11,078	.20	2.37
	16-20 July	N	9,787	.32 (.09)	71,067	.14	2.48
	16-20 August	N	32,269	.48 (.20)	283,256	.11	2.55
	14-19 September	N	19,139	.49 (.07)	153,952	.12	2.69
	13-17 October	N	19,348	.55 (.11)	185,019	.11	2.82
	16-20 November	N	4,637	.45 (.13)	42,184	.11	2.48
	16-20 December	N	1,146	.57 (.05)	7,542	.15	2.73
	MEAN 1970		7,780	.48	64,909	.16	2.56
1972	15-19 May	M	952	.51 (.11)	7,618	.13	3.07
	12-16 June	M	3,410	.28 (.08)	27,453	.12	2.84
	10-14 July	M	31,963	.27 (.09)	358,969	.09	2.77
	MEAN 1972		12,108	.35	131,347	.11	2.89

Table 5. Richness and evenness components of diversity for inshore waters of Lake Ontario during June-July (1969-1972).

Date	Diversity (bits)	Richness	Evenness
10 July 1969	1.90	3.92	1.71
16 July 1969	1.57	3.87	1.41
20 July 1970	2.07	2.60	2.07
23 July 1970	2.41	1.80	2.41
30 July 1970	2.14	2.70	1.98
12-16 June 1972	2.84	5.37	2.22
10-14 July 1972	2.77	4.54	2.10

ANNUAL PROGRESS REPORT

ALGAL NUTRIENT AVAILABILITY AND LIMITATION IN LAKE ONTARIO DURING IFYGL

Grant Number 800537

July 1, 1972 - June 30, 1973

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OBJECTIVES OF THE PROJECT

The objectives of this project were to 1) determine the limiting nutrient or nutrients in tributary and open waters of Lake Ontario with the standard Algal Assay Procedure (AAP) test; 2) estimate the extent of nutrient regeneration from *Cladophora* after death of the organism; and 3) determine the availability to algae of particulate-phosphorus forms in tributary waters, urban stormwater drainage, and precipitation, and the extent of mineralization of particulate nitrogen in tributary waters.

The original operational plan also included a study of the nitrogen and phosphorus nutritional status of *Cladophora* growing along the New York State shore. This project and much of the *Cladophora* nutrient regeneration study had to be curtailed because of the difficulty of receiving fresh algal samples. The funds to be used for these projects were instead used to sample the New York tributaries during the high flow period of 1973.

STATUS OF THE PROGRAM

Very limited *Cladophora* nutrient regeneration studies were performed during the fall and summer of 1972, along with some work on nitrogen and phosphorus availability in tributary and runoff waters. The major part of the sampling for the bioassay program was accomplished during field trips on 6-7 April, 30 April-1 May, 27-28 May, and 15-17 June, 1973. Figure 1 shows the sampling sites for tributaries and open lake stations. Samples have also been received from the New York State Department of Environmental Conservation since July of 1972, and from Dr. Moore in Oswego since February of 1973. New York rain gage water samples were not received until July of 1973, so that this phase of the program is considerably behind schedule.

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*This project is also conducted at the University of Wisconsin, Madison, Wisconsin.

Laboratory work on all samples except the last set of open lake water and the rain gage water has been essentially completed. As specified in our contract, we will try to bioassay additional rain gage samples as they are received. With this exception, the laboratory research should be completed by mid-August, 1973.

SUMMARY OF RESULTS TO DATE

Cladophora Nutrient Regeneration

Tables I-III summarize the limited data available from fresh *Cladophora* samples collected in Lake Ontario and (for comparison) Lake Mendota, Wisconsin. The cellular nitrogen (N) and phosphorus (P) data were obtained from Kjeldahl-digested and wet-ashed subsamples of algae, on an oven-dry basis. The subsamples were spun-dry to oven-dry weight, so that the cellular N and P levels of the spun-dry algae used in the regeneration tests could be calculated. The samples were stored under aerobic conditions in darkness at 22-27°C., with and without chloroform for phosphate regeneration and without chloroform for nitrate regeneration.

Tables I and II show that the percent of cellular phosphate converted to dissolved reactive phosphorus (DRP) reactive to a molybdenum-blue color reagent (Standard Methods, 13th ed., 1971) was extremely variable, ranging from 21 to 100 percent. Generally, the maximum extent of regeneration was completed by 5-7 days with chloroform and by 50 days without chloroform.

The conversion of cellular nitrogen to nitrate (Table III) was somewhat less variable, with a range of 12-40 percent. The nitrogen mineralization was relatively show, with increases in NO_3^- still occurring between 50 and 100 days.

Figure 1

Lake Ontario and Tributary Water Sampling Sites

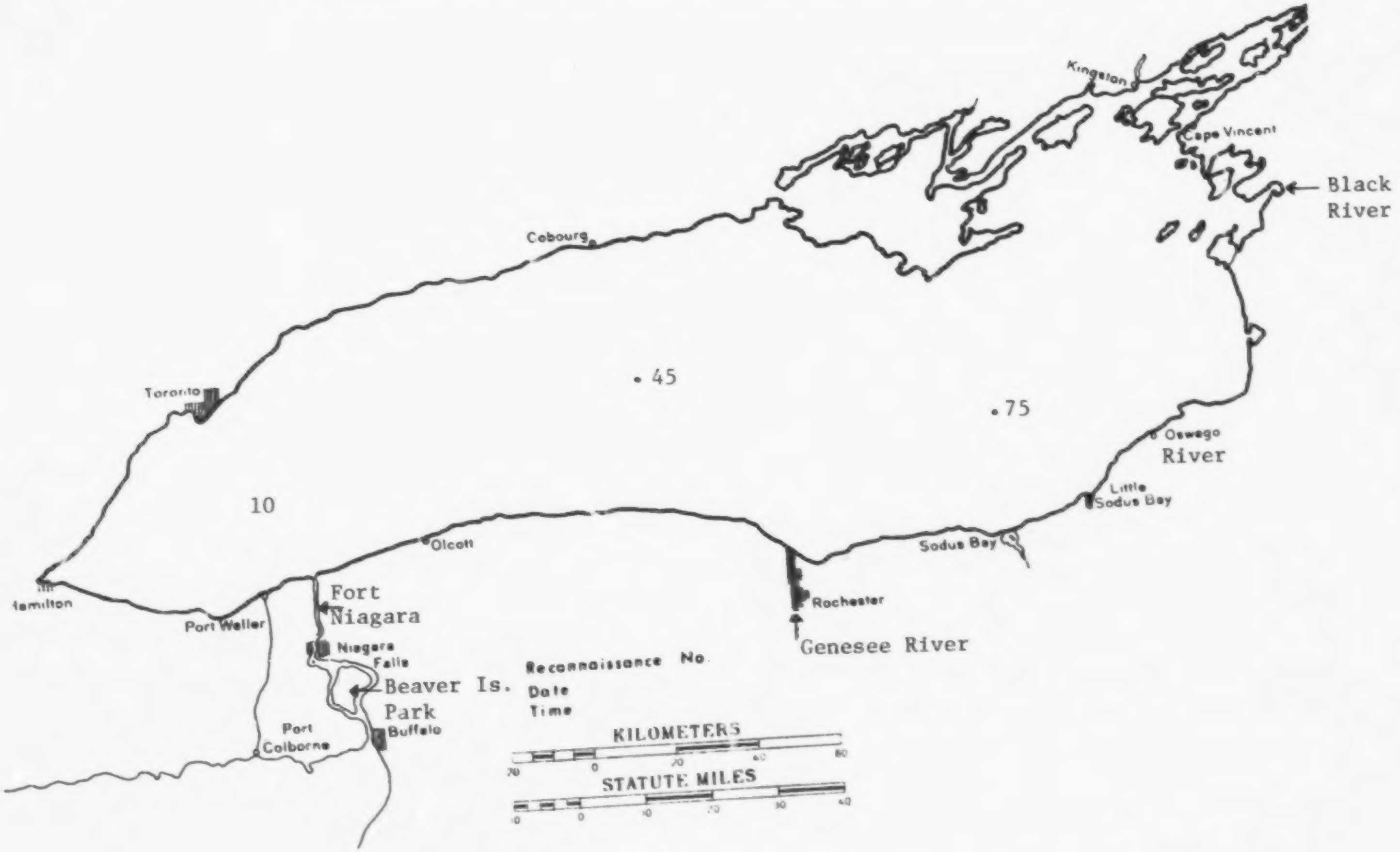
Kingston
Cape Vincent
Black River
Cobourg
Toronto
• 45
• 75
Oswego
River
Little
Sodus Bay
10
Olcott
Sodus Bay
Hamilton
Port Weller
Fort
Niagara
Rochester
Genesee River
Niagara
Falls
Beaver Is.
Park
Reconnaissance No.
Date
Time
Port
Colborne
Buffalo
KILOMETERS
20
0
20
40
60
80
STATUTE MILES
10
0
10
20
30
40

Table I

Release of Dissolved Reactive Phosphorus from Chloroformed Cladophora

Sample	Date Collected	P Content ug P/mg Algae	Incubation, Days	P Release in 5 days, ug P/mg Algae (Range)*	% P Released (Range)*
Mendota - 1	15 Jun 72	0.9	5	0.59-0.94	66-104
Mendota - 2	23 Jun 72	1.1	5	0.86-1.3	75-118
Oswego	8 Jul 72	0.7	5	0.24-0.46	34-65
Rochester	21 Jul 72	1.1	5	0.70-0.90	64-82

* Three portions of algae from each sample.

Table II

Release of Dissolved Reactive Phosphorus from Cladophora Incubated in Darkness

Sample	Date Collected	P Content ug P/mg Algae	Incubation, Days	Max P Release in 50 Days ug P/mg Algae (Range)*	% P Released (Range)*
Mendota - 1	15 Jun 72	0.9	50	0.50-0.58	57-64
Oswego	8 Jul 72	0.7	50	0.64-0.86	90-121
Rochester	21 Jul 72	1.1	51	0.87-0.98	79-89
Toronto	16 Aug 72	1.6	50	0.34-0.38	21-24

* Three portions of algae from each sample.

Table III

Formation of Nitrate
from Cladophora Incubated in Darkness

Sample	Date Collected	N Content ug N/mg Algae	Incubation, Days	NO_3-N Released in 100 Days ug N/mg Algae (Range)*	% N Released (Range)*
Mendota-1	15 Jun 72	20	102	4.4-4.9	22-24
Oswego	8 Jul 72	57	100	6.8-10	12-18
Rochester	21 Jun 72	22	100	8.4-8.7	38-40
Toronto	16 Aug 72	27	100	6.2-9.0	23-33

*Three portions of algae from each sample

AAP Study on Nutrient Limitation in New York Tributary Waters and Lake Ontario Water

All samples assayed were autoclaved at 15 psi for 15 minutes, then cooled and filtered through 0.45 micron pore-size millipore filters before inoculation with nutrient spikes and *Selenastrum capricornutum*. Growth stimulation was followed by absorbance measurements (750 nm) at 48-hour intervals until a plateau was reached.

Figure 2 is a representative summary of an AAP test nutrient spike study, performed on the Genesee River sample #34, collected 7 April 1973. Only the averages of three replicate flasks of each treatment are shown, for clarity. Neither N spikes nor N+ micronutrient spikes significantly enhanced the growth of *Selenastrum* in the sample over the unspiked control. In contrast, the phosphorus spike alone caused a significant growth response, indicating phosphorus limitation. No conclusions about limitation in the rivers can be made, however, until all the data have been compiled from the spring sampling trips.

Carbon-14 assimilation rate measurements made on Lake Ontario water (open-lake and near shore) collected before February 1973, generally showed stimulation of the natural phytoplankton only when spiked with P+N, or P+N+micronutrients.

The data from water collected on spring sampling trips by the Canadian Centre for Inland Waters is still being processed.

Nitrogen Mineralization in New York Rivers

Table IV shows the results obtained thus far from river samples collected in the spring of 1973. The results are expressed as the maximum percent of the total N which appeared as nitrate in the incubations. In some cases the experiments have not been completed, so the most recently reported value is given.

The overall range of nitrogen availability was found to be 60-91 percent of the initial total nitrogen (total Kjeldahl-N plus nitrate) of the samples. In all cases, the final ammonia levels were not significant compared to the nitrate levels, so that "readily available" nitrogen was considered to be represented by nitrate alone. Experimental results from later samples collected in May and June have not yet been evaluated.

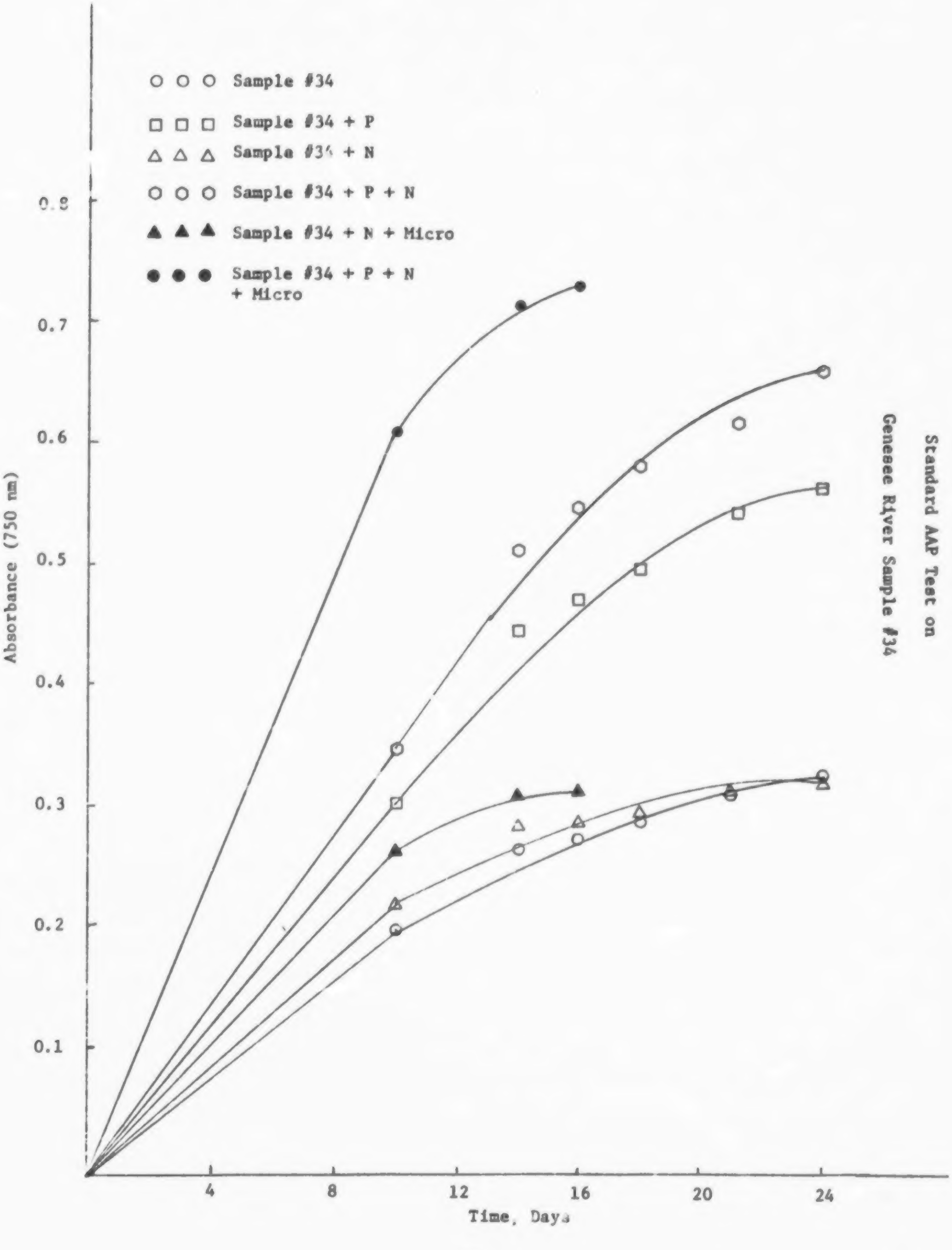

Figure 2
Standard AAP Test on
Genesee River Sample #34

Phosphorus Availability in Tributary Waters to Lake Ontario

The samples used for particulate-phosphorus availability studies included those from the New York rivers and from the Genesee River Basin study. Table V shows the sampling stations and the major land use classifications of the Genesee Basin study. Only selected samples were studied for particulate-phosphorus (PP) availability because of the very low concentrations of PP in many of the samples. Tables VI and VII summarize the phosphorus chemistry of the samples extracted with dilute $HCl-H_2SO_4$, 0.1N NaOH, Dowex-1 anion exchange resin, or with Selenastrum in growth assays. Only two samples showed a PP availability of greater than 50 percent; these were found with acid extractions. Extractions with base and resin showed less available P than did acid extractions in most cases, and 18-day algal assays showed the lowest levels of available P. Autoclaved particles showed availability percentages similar to basic extracts. In all tests, the particles were isolated on 0.45 micron pore size filters. Total P, total soluble P and PP data are based on a persulfate digestion method (Standard Methods, 13th ed., 1971).

The same types of tests were conducted on Genesee River particulate matter, as shown in Table VIII. The results of acid extracts were extremely variable, while the results of the base, resin and algal extractions were similar to those from the Genesee Basin study (Table VII).

Bioassays of river particulate matter generally showed that less than 6 percent was available to Selenastrum over 18 days (Tables VIII and IX). In contrast, autoclaved particles released 26-57 percent of their phosphorus for algal growth.

In an effort to directly estimate the availability of total phosphorus (TP) in the river samples, chloroform was added and the resultant increase in DRP was monitored with time, as proposed by Berman (1970). Figure 3 illustrates a typical 7-day release pattern for an Oswego River sample, with and without a condensed phosphate (sodium tripolyphosphate--TPP) spike added to demonstrate the presence of active phosphatases in the chloroformed sample. The final DRP level exceeded the initial total soluble P (TSP) value, demonstrating that some of the released DRP must have come from an insoluble source, i.e., particulate-phosphorus. Table X summarizes the data from such tests run on other river samples. The Genesee results were extremely variable, while the results from other rivers seemed to be less variable, with averages of 33-64 percent of the TP available in the test.

Table IV

Mineralization of Kjeldahl Nitrogen

in Samples Incubated in Darkness

Sample No.	Date Collected	NO_3^--N, mg N/1		Day Maximum Observed	Initial Total N,* mg N/1	Max % Total N Avail as NO_3^--N mg N/1
		Initial	Maximum Observed			
Oswego R - #28	2 Mar 73	0.61	1.06	82	1.34	79
Oswego R - #31	28 Mar 73	0.68	1.01	64**	1.27	80
Oswego R - #35	7 Apr 73	0.56	1.05	64**	1.16	91
Oswego R - #43	1 May 73	0.46	0.92	28	1.42	65
Genesee R - #34	7 Apr 73	0.98	1.32	64**	2.21	60
Genesee R - #42	1 May 73	0.56	1.05	28	1.52	69
Niagara R - #41	30 Apr 73	0.14	0.32	28	0.45	71
Black R - #36	7 Apr 73	0.47	0.56	64**	0.89	63
Black R - #44	1 May 73	0.24	0.37	28	0.59	63

* Kjeldahl N + NO_3^--N before incubation

** Experiment still in progress

Table V

LOCATION OF SAMPLING STATIONS
GENESEE RIVER BASIN

Station No.	U.S.G.S. Map Name	Land Use	
1	Byron	Cropland	Spring Creek
2	Rochester East	Urban	Allen Creek
3	Geneseo	(Beginning of pasture)	
4	Geneseo	Pasture	Jaycox Creek
5	Geneseo	(Beginning of Pasture)	
6	Springwater	Forest	Briggs Gully
7	Dansville	High density residential	
8	Dansville	Beginning of H.D.R.	
9	Andover	Brushland	East Valley Creek

Table VI

Phosphorus Forms

in Genesee River Basin Samples

Sample Number	Date Collected	Phosphorus, ug P/1			
		DRP	TSP	TP	PP
402-6	6 Oct 72	72	77	118	41
402-8	3 Nov 72	70	78	188	110
404-8	2 Nov 72	182	193	350	157
407-8	2 Nov 72	27	29	361	332
409-8	2 Nov 72	<1	8	131	123
402-9	15 Nov 72	55	66	112	46
409-9	14 Nov 72	14	26	2140	2110
502-1	15 Dec 72	27	35	60	25
502-7	22 Mar 73	24	26	69	43
507-7	20 Mar 73	---	4	39	35
502-8	4 Apr 73	19	27	59	32
504-8	4 Apr 73	54	60	452	392
507-8	3 Apr 73	6	4	29	25
507-9	17 Apr 73	2	2	27	25
502-10	1 May 73	15	22	79	57
502-11	6 May 73	37	46	81	35
507-11	15 May 73	2	5	22	17
501-12	30 May 73	3	12	60	48
502-12	30 May 73	43	55	165	110
507-12	30 May 73	2	4	32	28
501-13	12-13 Jun 73	1	4	31	27
507-13	12-13 Jun 73	5	9	239	230
501-14	26 Jun 73	6	7	38	31
502-14	26 Jun 73	59	66	129	63
507-14	25 Jun 73	9	10	284	274

Table VII

Chemical and Biological Extraction of Particulate-Phosphorus in Genesee River Basin Samples

Station No.	Sample Number	Average Per Cent of Particulate-P Extracted by Acid	Base	Resin	Algae	Algae (Particles Autoclaved)
1 (Byron)	501-12	25	11	1	< 4	--
	501-13	18	18	7	--	16
	501-14	22	10	10	<10	20
	Averages	22	13	6	< 7	18
2 (Rochester East)	402-6	42	27	27	--	--
	402-8	40	29	24	--	--
	402-9	60	37	22	--	--
	502-1	--	--	--	<12	--
	502-7	--	37	28	22	--
	502-8	--	25	18	21	--
	502-10	--	--	--	24	--
	502-11	46	29	28	< 1	--
	502-12	49	27	27	< 5	--
	502-14	52	27	25	< 2	34
	Averages	48	30	25	<12	34
4 (Geneseo)	404-8	29	18	17	--	--
	504-8	29	19	18	7	--
	Averages	29	18	18	7	--
7 (Dansville)	407-8	35	18	10	--	--
	507-7	34	26	6	< 3	--
	507-8	--	32	8	< 5	--
	507-9	29	10	12	< 2	--
	507-11	28	16	16	< 3	--
	507-12	30	24	14	< 1	--
	507-13	28	15	14	--	8
	507-14	30	10	5	2	10
	Averages	30	19	11	< 3	9
9 (Andover)	409-8	23	16	7	--	
	409-9	35	21	11	--	
	Averages	29	18	9	--	

Table VIII

Chemical and Biological Extractions of Genesee River Particulate-Phosphorus

Sample No.	PP ug P/1	Average Per Cent of Particulate-P Available to Acid	Base	Resin	Algae (Selenastrum)	Algae (Particles Autoclaved)
Genesee R - #34	360	79	11	9	2	--
Genesee R - #42	105	58	18	24	<6	--
Genesee R - #51	62	44	27	31	<2	41
Genesee R - #58	146	21	12	5	<1	36

Table IX

Biological Extractions of New York River Particulate-Phosphorus

Sample No.	PP ug P/1	Average Per Cent of Particulate-P Available to Algae (Selenastrum)	
		Particles Not Autoclaved	Particles Autoclaved
Niagara R - #50	19	<5	57
Niagara R - #56	26	--	33
Oswego R - #43	50	<1	--
Oswego R - #47	48	<2	--
Oswego R - #52	47	<2	44
Oswego R - #59	86	--	32
Black R - #44	20	5	--
Black R - #53	25	<3	45
Black R - #60	75	--	26

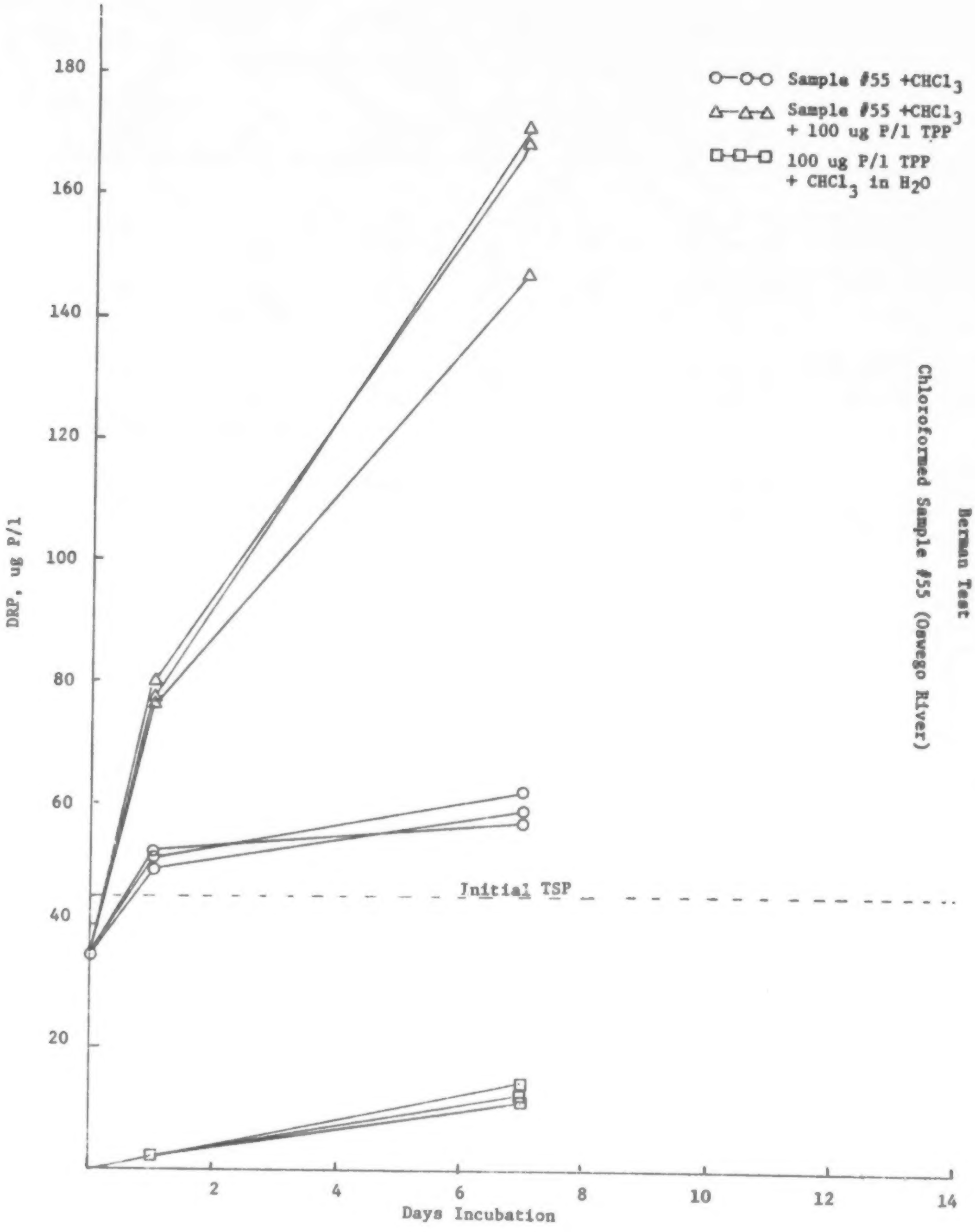

Figure 3
Berman Test
Chloroformed Sample #55 (Oswego River)

Table X

Increase of Dissolved Reactive Phosphorus During Incubation of New York River Water with Chloroform

		DRP, ug P/1				
Sample No.	Date Collected	Initial	+$CHCl_3$ (1 day)	+$CHCl_3$ (7 days)	TP ug P/1	% TP available +$CHCl_3$ (7 days)
Fort Niagara						
Niagara R - #27	26 Feb 73	4	9	10	18	56
Niagara R - #33	28 Mar 73	5	11	14**	34	41
Niagara R - #50	27 May 73	1	12	16	26	62
Niagara R - #56	15 Jun 73	26	27	30*	59	51
					Average	53
Beaver Island Park						
Niagara R - #49	27 May 73	2	14	22	51	43
Niagara R - #57	15 Jun 73	3	17	20*	86	23
					Average	33
Genesee						
Genesee R - #34	29 Mar 73	26	32	36**	386	9
Genesee R - #51	28 May 73	104	111	122	173	70
Genesee R - #58	16 Jun 73	49	63	76*	204	37
Oswego						
Oswego R - #22	7 Aug 72	58	64	71	93	76
Oswego R - #23	7 Aug 72	49	66	63	96	69
Oswego R - #24	1 Sep 72	4	59	46	88	67
Oswego R - #26	1 Sep 72	79	96	75	154	62
Oswego R - #29	12 Mar 73	78	80	82	131	62
Oswego R - #31	28 Mar 73	43	46	49	95	52
Oswego R - #35	29 Mar 73	47	62	67**	105	64
Oswego R - #52	28 May 73	50	61	70	104	67
Oswego R - #54	31 May 73	40	49	57	87	66
Oswego R - #55	4 Jun 73	35	51	59	96	61
Oswego R - #59	17 Jun 73	46	77	88*	147	60
					Average	64
Black						
Black R - #25	28 Aug 72	14	19	16	53	30
Black R - #36	29 Mar 73	7	11	15**	34	44
Black R - #53	28 May 73	5	15	17	41	41
Black R - #60	17 Jun 73	13	28	37	99	37
					Average	38

* 8 days
** 9 days

Dark, long-term incubations of river water with and without Dowex-1 anion exchange resin have also been conducted on these samples; however, the data have not been completely evaluated at this time. In addition, AAP-type growth assays have recently been run on autoclaved, filtered samples to quantitate the level of available P resulting from such treatment.

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ANNUAL REPORT

Grant Number R-800605

ANALYSIS OF PHYTOPLANKTON COMPOSITION AND ABUNDANCE DURING IFYGL

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Great Lakes Research Division
University of Michigan

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This project was initiated as part of an integrated series of investigations of Lake Ontario under the general aegis of the International Field Year Great Lakes. In its original conception this project was planned primarily as an attempt to construct a precise model of the hydrological characteristics of Lake Ontario. Since it was recognized that the unique bank of physical data generated by this project would have great utility in constructing a more general process model of the Lake Ontario ecosystem, an attempt has been made to also gather a similar bank of coherent biological and chemical data to facilitate the construction of the more general model. This effort was carried out largely within the constraints imposed by the demands of original project concept.

The specific objectives of the particular project discussed here are to provide an assessment of the phytoplankton populations present in the lake and their seasonal cycles of distribution and abundance. Operationally, the problem was approached through a sampling design of 60 stations (shown on Figure 1) sampled at monthly intervals during prime growth periods and bimonthly otherwise. Samples are taken from standard depths at all stations. At deepest stations, a total of 12 samples are taken and sampling sequence is truncated in shallower depths.

The major effort in the project is devoted to development of population abundance estimates for the species of phytoplankton occurring in Lake Ontario. Method used is direct microscopic identification and enumeration from material prepared as semipermanent slides in the field. Rapid gross estimates of total particle abundance are also made on all samples, using an automatic optical occlusion particle counter-sizer operating in the range of 5-150μm.

Splits from the same samples used in preparation of slides analyzed in the project are also filtered, preserved, and set aside as permanent archival references. It was felt that this project furnished a unique opportunity to develop a coherent set of base line information of the type sadly lacking in the Laurentian Great Lakes. At the end of the project, this material will be deposited with the Smithsonian Institution.

Partially as an independent cross calibration, and partially as a comparison with the methods used by other projects, a limited number of extracted chlorophyll determinations were made by the fluorometric method generally utilized in our laboratory. These measurements were made on samples taken from 5 "master" stations. Primary responsibility for development of standing crop estimates through chlorophyll measure is part of another project.

There has been considerable deviation from the original concept and plan in the actual sampling operation serving this project. The original plan called for sampling beginning in April and proceeding throughout the year with the same basic array of stations being sampled on every cruise. Due to the unavailability of a sampling platform, it was necessary to "scratch" the planned cruise in April of 1972. Due to adverse weather conditions and the constraints on platform availability, sampling on the May cruise was only about 50% effective. Due to these problems, plus the fact that highly unusual weather conditions introduced the possibility that biological responses in the spring of 1972, during the grand period of phytoplankton growth might be atypical, led to the consideration of extension of the originally planned sampling exercise. After consultation with representatives of other projects involved in biological and chemical measurements, it was decided to extend the sampling operation through June of 1973. Due again to the constraints on availability of sampling platforms, it was necessary to somewhat restrict the number to stations sampled during each cruise. The total effect on this particular project has been to considerably increase the amount of time devoted to field sampling operations and to somewhat increase the total number of samples that it is necessary to analyze beyond the number originally planned. Requests for time extension and funding increase consistant with the increased work load have been submitted with this year's renewal request.

Current Status of Project

Archival Samples

All archival samples have undergone final processing and labels have been printed. Material is presently being labeled and packed for shipment to final repository. A total of 3677 samples are available. Summary listing of the samples available is shown in Appendix A. Printouts of sample labels can be furnished on request. This phase of the project is essentially on schedule.

Particle Count Analyses

Initial analysis has been completed on all samples and raw data from these runs is given in Appendix B. Work is presently underway to calibrate these values against other estimates of phytoplankton standing crop. Card form raw data summaries can be furnished on request, but potential users should be advised that raw data reflects total particulates. This phase of the project is essentially on schedule. Further progress will depend on availability of chlorophyll and cell count data.

Microscopic Cell Counts

Analysis has been completed for all surface stations. Summary representations of total cell numbers are included in Tables 1-10 following. Numerical data for particular stations or distributions of particular species can be furnished if urgently needed but we ask that such requests be kept to a minimum due to expense involved in dumping interum summaries. Current emphasis in this phase of project is in completing analyses of depth series data from master stations. This phase of project has suffered most from extension of sampling program due to the necessity of diverting personel from lab to field operations. At present we estimate that this phase of the investigations is approximately 2 months behind originally projected schedule.

Summary of Results to Date

Perhaps the most striking feature of the phytoplankton data we have developed so far is the extreme variability of the phytoplankton assemblage both in respect to total abundance and in respect to the distribution of particular entities.

The dominant seasonal pattern, as would be expected, appears to be the development of a spring bloom beginning at isolated localities nearshore during March and developing in all nearshore waters by April. In 1973, high concentrations of phytoplankton were first noted at isolated stations on both the north and south shores in March (Fig. 8). By April of the same year cell counts over 2000 cells/ml were noted at most stations on the north shore east of 79° (Fig. 9). Total abundance figures were less for stations on the south shore, running between 1000 and 2000 cells/ml, except at stations near Rochester and near Thirty Mile Point, where they exceeded 2000 cells/ml. During this sampling period counts appeared to be lower in the extreme western end of the lake and higher in the northeastern island area. There, however, did not appear to be any consistant east-west trend in phytoplankton abundance in the offshore open water region of the lake. During the May 1972 sampling period (Fig. 1) total cell counts over 2000 cells/ml were noted at shoreward stations east of 78° 30' with highs of over 5000 cells/ml at stations in Mexico Bay and in the North Channel-Prince Edward Bay region. At this time cell counts in the mid-lake region were on the order of 1000 cells/ml. During this sampling period there appeared to be a trend toward lower values in the western end of the lake, both in the waters nearshore and in the open lake but a large portion of the eastern region was not sampled. During the June 1972 sampling period (Fig. 2) total cell counts over 2000 cells/ml were noted at most stations sampled. Much lower abundances were noted at a rather narrow band of stations offshore (near 43° 30' N) and near Niagara. Much higher counts were found over a wide area near Toronto and at two isolated stations in the eastern end of the lake. During the June 1973 sampling period, however, distribution was much less consistent (Fig. 10). Total cell counts greater than 5000 cells/ml were noted at isolated stations offshore and there did not appear to be any consistent trend, either east-west or with respect to distance from shore. In July 1972, total phytoplankton abundance declined rather drastically from levels reached in June of the same year (Fig. 3). At this time, highest cell counts were found at stations just east of Niagara. Somewhat lower peaks, somewhat more than 2000 cells/ml, were noted at isolated stations near Toronto and offshore in the eastern end of the lake. In August of 1972 total phytoplankton abundance declined at all stations in the western sector of the lake, with somewhat higher abundances being maintained in the vicinity of Toronto and Niagara (Fig. 4). Total cell counts in the eastern sector, however, increased with total cell counts in excess of 2000 cells/ml being found at stations near Rochester and at all stations sampled in the eastern islands region. During the October 1972 sampling period phytoplankton abundance was moderately high at all stations sampled, with no particularly striking areal pattern being evident (Fig. 5). Highest abundances were noted at stations between Hamilton and Niagara at stations nearshore. Total phytoplankton abundance continued to decline and during the November 1972 sampling period (Fig. 6). No particularly striking trends were evident, but there appeared to be a tendency toward higher abundance in the sectors of the lake near Toronto and Rochester. Lowest overall abundances noted during the study to date were found in February 1973 sampling (Fig. 7). Total cell counts were less than 200 cells/ml at most stations in the southern and western portions of the lake, with somewhat higher levels being found in the vicinity of Toronto, Niagara, Rochester and Oswego. Higher values were found at stations near the northern and northeastern shore, with highest values, on the order of over 1500 cells/ml, found at stations south and east of Prince Edward Point. It appears that during this sampling period phytoplankton abundance was significantly higher at all stations in the northeastern sector of the lake, although the reduced sampling density makes the overall distribution pattern somewhat difficult to interpret.

In inspecting the summaries presented in the figures, it should be kept in mind that the numbers refer only to cell counts and are not correct for cell volume. In some cases further refinement of the data may tend to smooth some of the apparent inconsistencies that are present, but it is doubtful that any major change in interpretation will result.

In some respects it is surprising that the phytoplankton density data do not more clearly reflect the presence of major pollution sources. In certain cases, such as June 1972 and February 1973, such trends are apparent but in many instances particularly high phytoplankton abundances are not obviously related to major pollution sources. Perhaps the most surprising result in this context is the apparent initiation of the spring bloom and consistently high values found in the northeastern sector of the lake.

It is apparent from inspection of the phytoplankton preparations that grazing may play a significant part in modifying apparent trends in phytoplankton abundance. Prepared slides from many localities have unusually high levels of protozoans and rotifers in addition to the phytoplankton. Although we have not made quantitative estimates of the abundance of these entities, it appears that their abundance is quite closely related to localities having apparent nutrient sources. Further analysis of this situation awaits input from the zooplankton projects.

Although we have not yet attempted to plot the distribution of particular species in detail, it is obvious from inspection of the raw data that there is an extermely high degree of variability in population dominance at different stations.

During the initial sampling period in May 1972 the predominant taxa were the smaller species of *Stephanodiscus*, including *S. minutus*, *S. tenuis*, *S. subtilis*, and at certain stations *S. binderanus*. Often large but highly variable populations of microflagellates were noted at most stations. The most abundant species were *Cryptomonas erosa* and *Rhodomonas minutus*, although several other species were occasionally present in high numbers. *Scenedesmus bicellularis* was particularly abundant at stations where high total counts were found. Most abundant taxa at offshore stations were *Melosira islandica*, *Asterionella formosa* and occasionally *Fragilaria crotonensis*. Occasional high populations of *Peridinium* spp., *Ankistrodesmus falcatus et var*., and *Anacystis incerta* were also noted. Although not numerically dominant at any station, *Surirella angustata* was common in most collections as was *Diatoma tenue var. elongatum*.

Essentially the same dominant assemblage was present in the June 1972 collections with *Stephanodiscus binderanus*, several species of microflagellates and *Scenedesmus bicellularis* being the overall predominant forms, particularly at stations having high standing crop levels. *Melosira islandica*, *Fragilaria crotonensis* and *Asterionella formosa* remained relatively abundant at some stations, particularly offshore. Isolated abundant occurrences of *Gloeocystis planctonica* and *Coccomyxa coccoides* were also noted.

During July the former of these two species continued to increase, while most of the dominant species in the early spring flora were on the wane. Microflagellates continued to be abundant but dominant forms at most stations were *Chrysochromulina parva* and *Dinobryon* spp. although *Cryptomonas erosa* continued to be abundant. *Stephanodiscus subtilis* and *Diatoma tenue* var. *elongatum* were the most abundant diatoms.

In August the dominant species at most stations were *Fragilaria crotonensis*, *Gloeocystis planctonica*, and several members of the genera *Anabaena*, *Oocystis*, and *Pediastrum*. At some stations the green flagellates *Eudorina* and *Phacotus* were quite abundant along with species of *Botryococcus*, *Ulothrix*, *Gomphosphaeria* and the only diatom which occurred in abundance at this time, *Stephanodiscus subtilis*. Although still present in most samples, the abundance of microflagellates was strongly reduced during this sampling period.

In October the abundance of microflagellates again increased with *Chrysochromulina parva*, *Rhodomonas minuta* and *Chlamydomonas* spp. being the primary taxa present. During this sampling period there was also a considerable relative increase in populations of the blue-green algae *Gomphosphaeria wichurae*, *Anacystis incerta*, and *A. cyanea*. The diatoms *Fragilaria crotonensis*, *Stephanodiscus subtilis* and *S. tenuis* were also conspicuous dominants at several stations.

In November the species of *Gomphosphaeria* and *Anacystis* and the microflagellate taxa which had become established the previous month remained abundant, but the diatom component of the flora was dominated by *Asterionella formosa*.

Somewhat surprisingly, the two blue-green taxa which were abundant in November remained conspicuous in the February collections. Otherwise the rather depauperate assemblages collected during this sampling period were dominated by *Stephanodiscus alpinus*, *S. hantzschii*, *Asterionella formosa* and *Scenedesmus bicellularis*.

During March the diversity of the phytoplankton assemblage appeared to increase substantially with the spring dominants noted the previous year being the most abundant taxa. This pattern of dominance remained about the same throughout the rest of the sampling period, with one notable exception. Stephanodiscus binderanus which had been the overall dominant, especially in June of the previous year, was strikingly reduced in abundance at all stations. Although it was still present in most collections, it tended to be replaced in dominance by the smaller species of Stephanodiscus referred to earlier and, particularly at some stations in June, by S. subsalsus which had been quite rare in collections taken the previous year.

The overall impression gained from our preliminary observations on Lake Ontario is that of a highly disturbed system in which the biological operators and seasonal trends differ considerably from those found in the upper Great Lakes. The striking nature of this difference led one of the people working on the project to make the succinct observation that Lake Ontario more resembles a series of eutrophic ponds flying in formation than it does a great lake so far as the phytoplankton flora is concerned.

So far as the species composition of the flora is concerned, the oligotrophic diatom and chrysophycean flagellate taxa which dominate the offshore waters of the upper lakes are conspicuous by their absence in Lake Ontario. Virtually all of the abundant taxa in the Lake Ontario flora either require, or are at least tolerant of, eutrophic conditions. Taken as a whole, the phytoplankton assemblage of the lake is quite unique. A number of the elements reported from other large, disturbed, lakes are present in Lake Ontario but their relative abundance and seasonal succession appears to be substantially different from most cases reported in the literature. The effect that this highly unusual primary producer community has on higher trophic levels can only be speculated upon at this time, but our observations would tend to indicate that, compared to the upper lakes, protozoans and rotifers are extremely abundant.

Although the limited overlap in sampling does not furnish sufficient basis for complete comparison, it is apparent that there were substantial differences between June of 1972 and June of 1973 in terms of both the composition of the phytoplankton flora and the abundance of phytoplankton at comparable stations. At this juncture, it appears that the relative instability of the phytoplankton flora in Lake Ontario may present serious problems in data interpretation and modeling activities.

It perhaps should be stressed that the phytoplankton count data presented here pertains only to near surface samples. Although the depth transect microscopic count data is not yet sufficiently developed to allow any generalization, inspection of the particle count data (Appendix A) indicates that there are large vertical differences within the mixed water column. The data do, however, suggest the accumulation of particles within the epilimnion, and particularly at the level of the thermocline, during sampling periods when thermal stratification was present.

Figure 1. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during May 1972 cruise. Area not sampled is indicated.

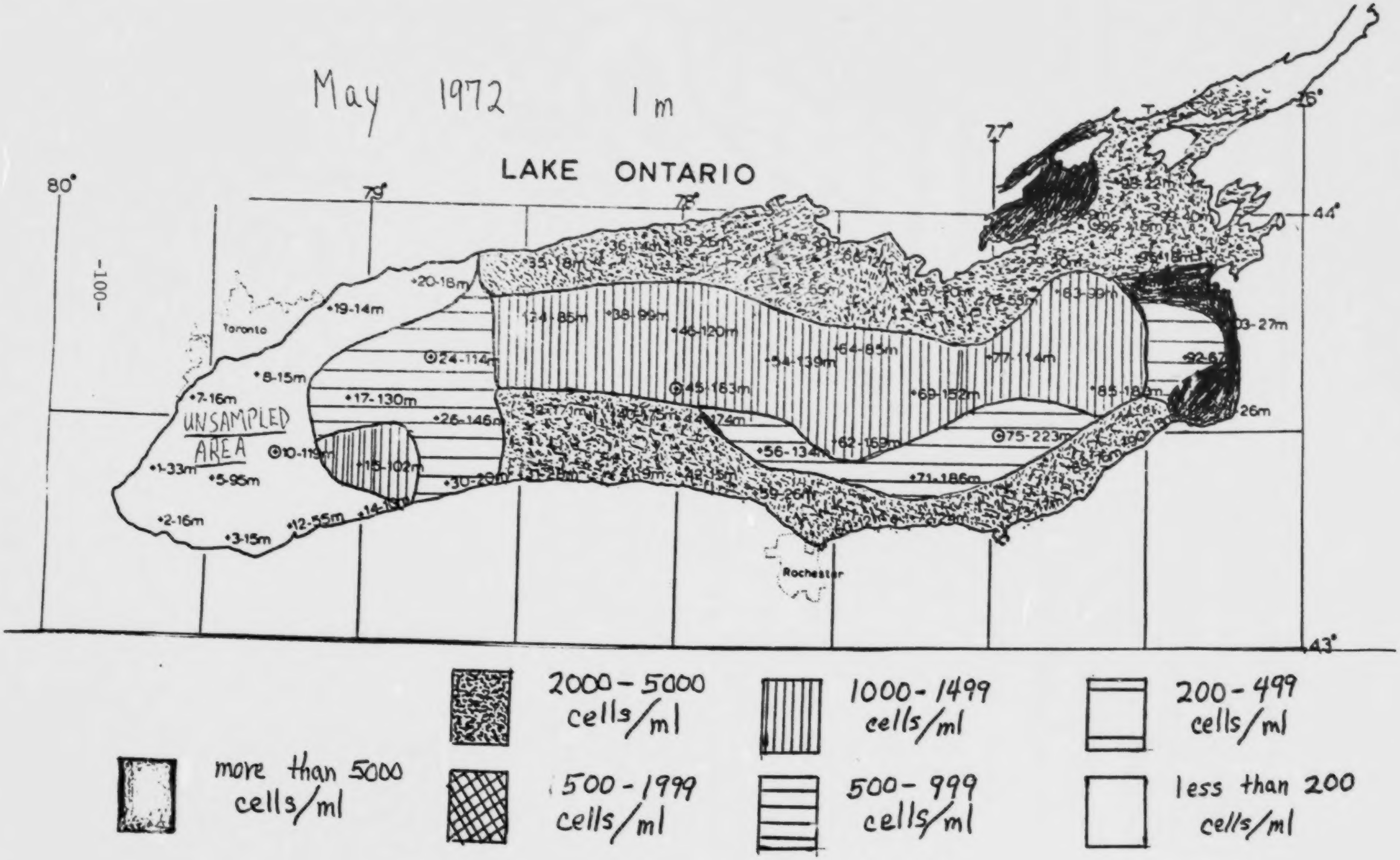

May 1972 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
UNSAMPLED AREA
•1-33m
•2-16m
•3-15m
•5-95m
•7-16m
•8-15m
⊙10-119m
•12-55m
•15-102m
•17-130m
•19-14m
•20-18m
⊙24-114m
•26-146m
•30-20m
•34-85m
•35-18m
•36-14m
•38-99m
•46-120m
⊙45-163m
•54-139m
•56-134m
•62-159m
•64-85m
•69-152m
•71-186m
⊙75-223m
•77-114m
•83-99m
•85-180m
•92-67m
26m
2000-5000 cells/ml
1000-1499 cells/ml
200-499 cells/ml
more than 5000 cells/ml
500-1999 cells/ml
500-999 cells/ml
less than 200 cells/ml

Figure 2. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during June 1972 cruise.

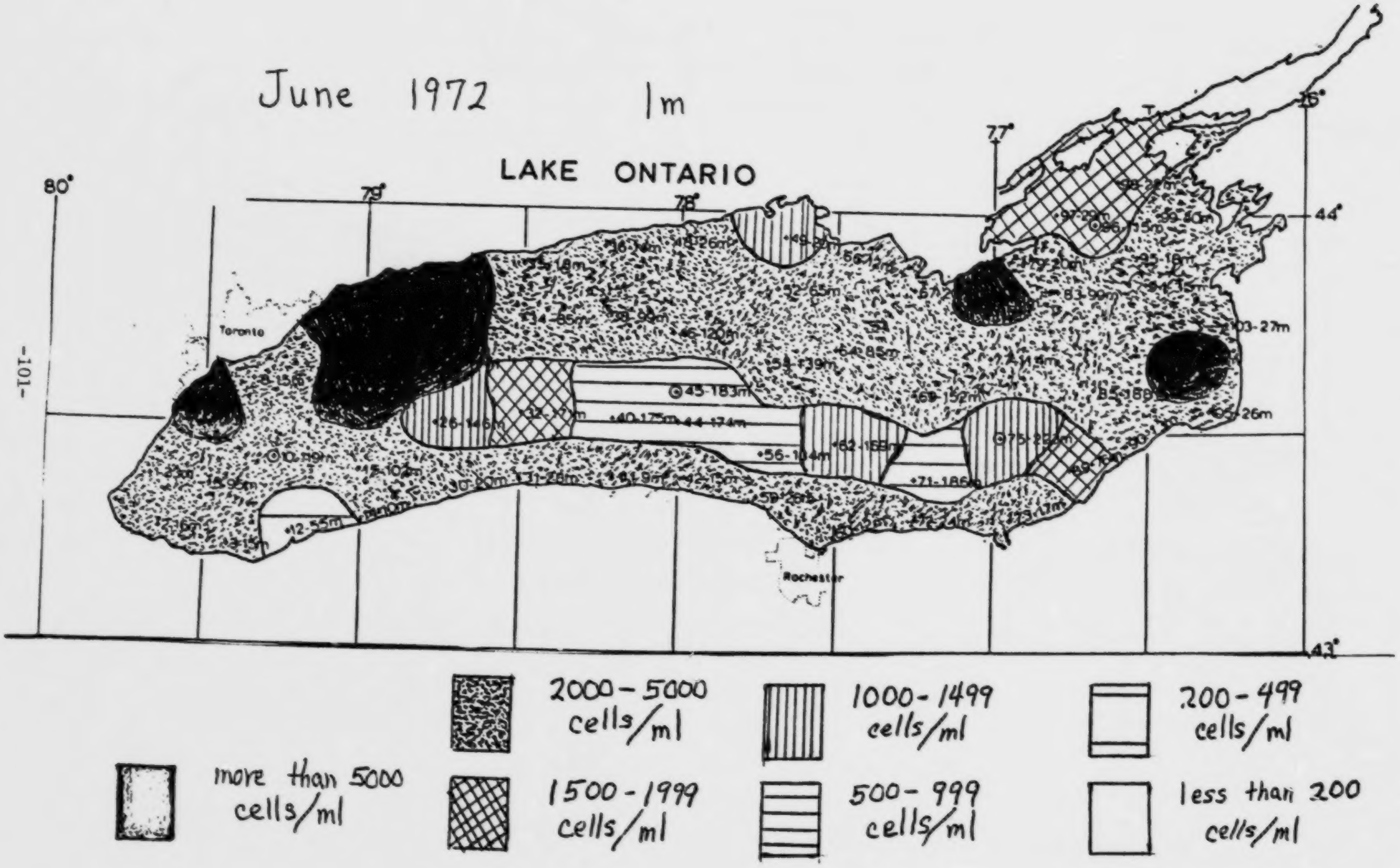

June 1972
1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
more than 5000 cells/ml
2000-5000 cells/ml
1500-1999 cells/ml
1000-1499 cells/ml
500-999 cells/ml
200-499 cells/ml
less than 200 cells/ml

Figure 3. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during July 1972 cruise.

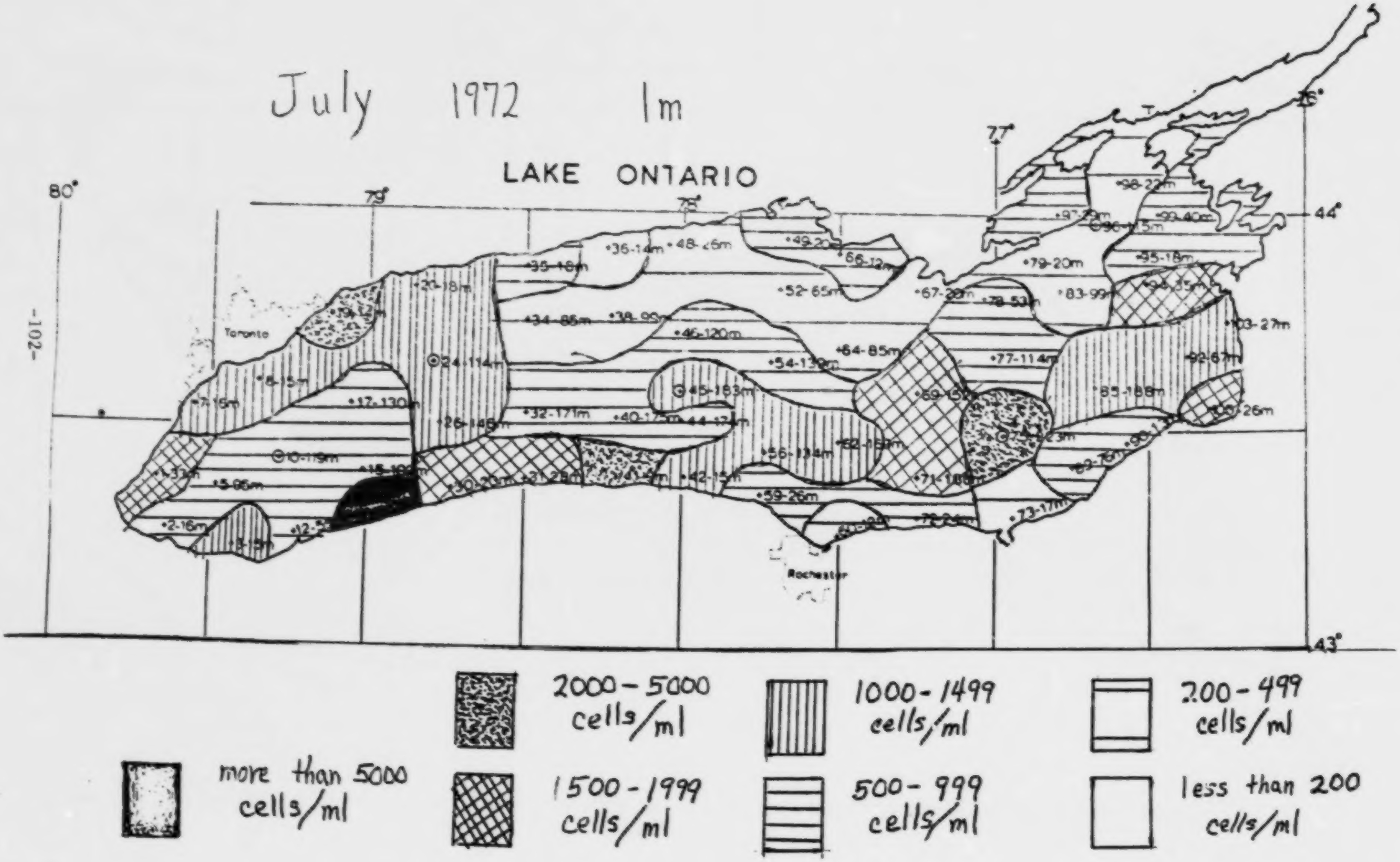

July 1972 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
•36-14m
•48-26m
•49-20m
•66-12m
•52-65m
•67-20m
•78-53m
•79-20m
•83-99m
•98-22m
•97-29m
•99-40m
•95-18m
•94-35m
•03-27m
•92-67m
•85-188m
•77-114m
•64-85m
•54-130m
•46-120m
•38-99m
•34-86m
•35-18m
•20-18m
•24-114m
•45-183m
•32-171m
•40-17m
•44-174m
•56-134m
•62-15m
•69-15m
•71-18m
•72-24m
•73-17m
•59-26m
•42-15m
•31-28m
•30-20m
•26-146m
•17-130m
•15-18m
•10-119m
•8-15m
•7-16m
•5-86m
•4-32m
•2-16m
•3-19m
•12-2
•00-26m
2000-5000 cells/ml
1000-1499 cells/ml
200-499 cells/ml
more than 5000 cells/ml
1500-1999 cells/ml
500-999 cells/ml
less than 200 cells/ml

Figure 4. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during August 1972 cruise.

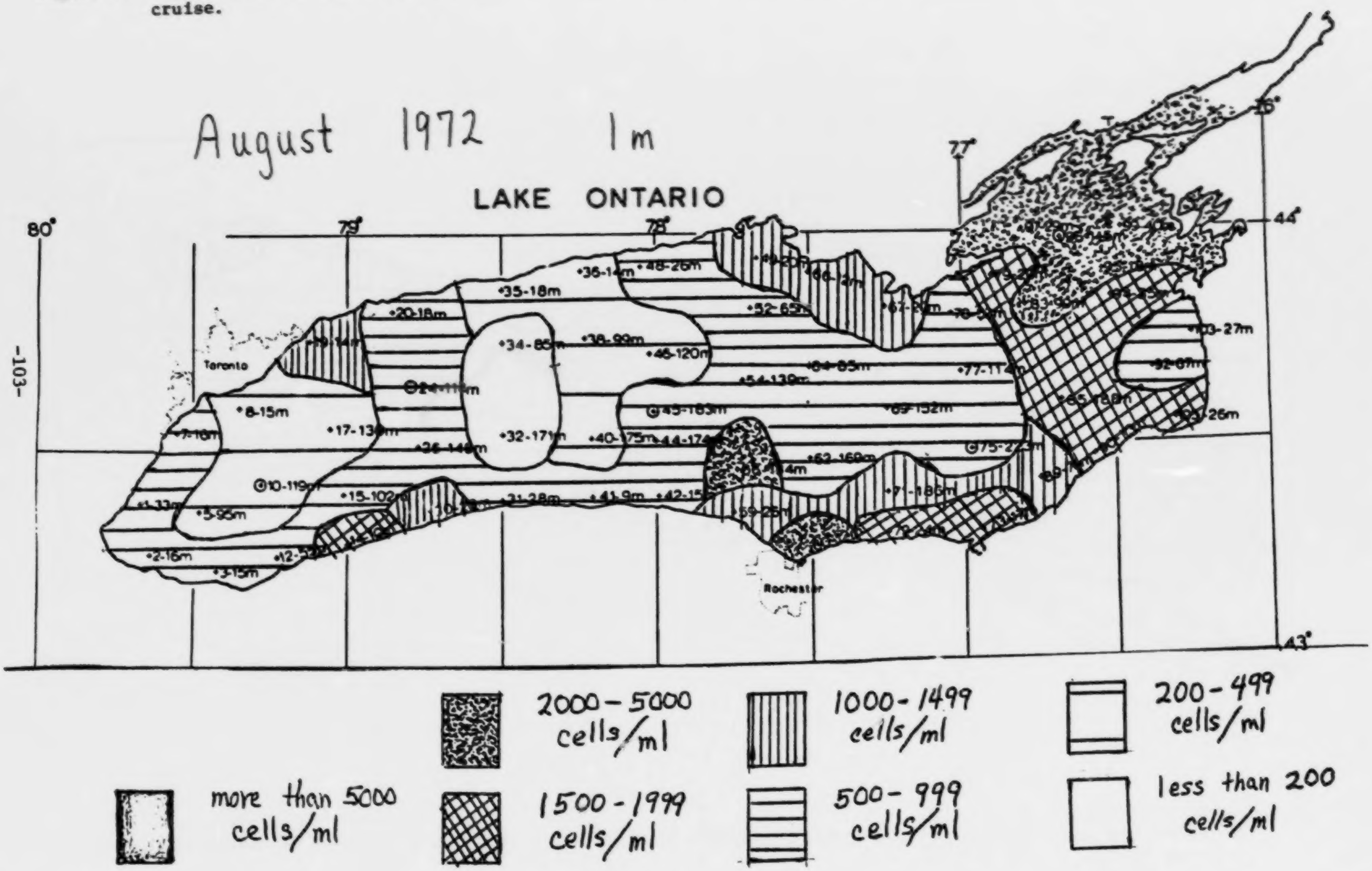

August 1972 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
•7-16m
•1-33m
•2-16m
•3-15m
•5-95m
•8-15m
⊙10-119m
•12-52m
•15-102m
•17-139m
•20-18m
⊙24-119m
•26-148m
•31-28m
•32-171m
•34-86m
•35-18m
•36-14m
•38-99m
•40-175m
•41-9m
•42-15
•44-174
⊙45-183m
•46-120m
•48-26m
•52-65m
•54-139m
•59-25m
•62-169m
•64-85m
•66-12m
•67-22m
•69-152m
•71-186m
⊙75-22m
•77-114m
•83-90m
•85-188m
•92-67m
•103-27m
2000 – 5000 cells/ml
1000 - 1499 cells/ml
200 - 499 cells/ml
more than 5000 cells/ml
1500 - 1999 cells/ml
500 - 999 cells/ml
less than 200 cells/ml

Figure 5. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during October 1972 cruise.

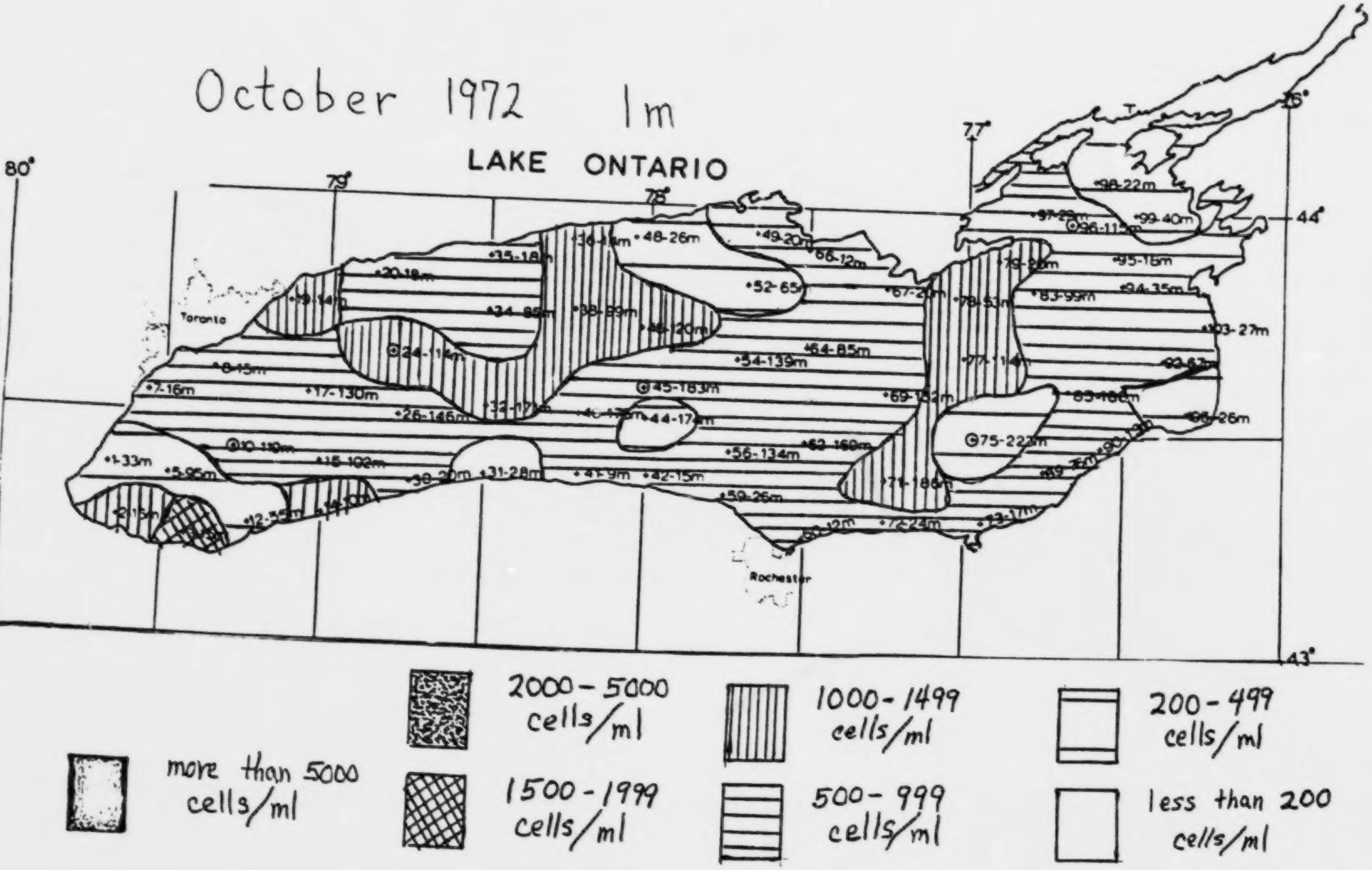

October 1972 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
•1-33m
•7-16m
•8-15m
•20-18m
•35-18m
•48-26m
•49-20m
•52-65m
•54-139m
•56-134m
•59-26m
•64-85m
•67-20m
•72-24m
•83-99m
•95-18m
•94-35m
•99-40m
•98-22m
•103-27m
•17-130m
•26-146m
•31-28m
•42-15m
•15-102m
•5-95m
⊙10-110m
⊙24-114m
⊙45-183m
⊙75-222m
⊙96-115m
2000 - 5000 cells/ml
1000 - 1499 cells/ml
200 - 499 cells/ml
more than 5000 cells/ml
1500 - 1999 cells/ml
500 - 999 cells/ml
less than 200 cells/ml

Figure 6. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during November 1972 cruise. Area not sampled is indicated.

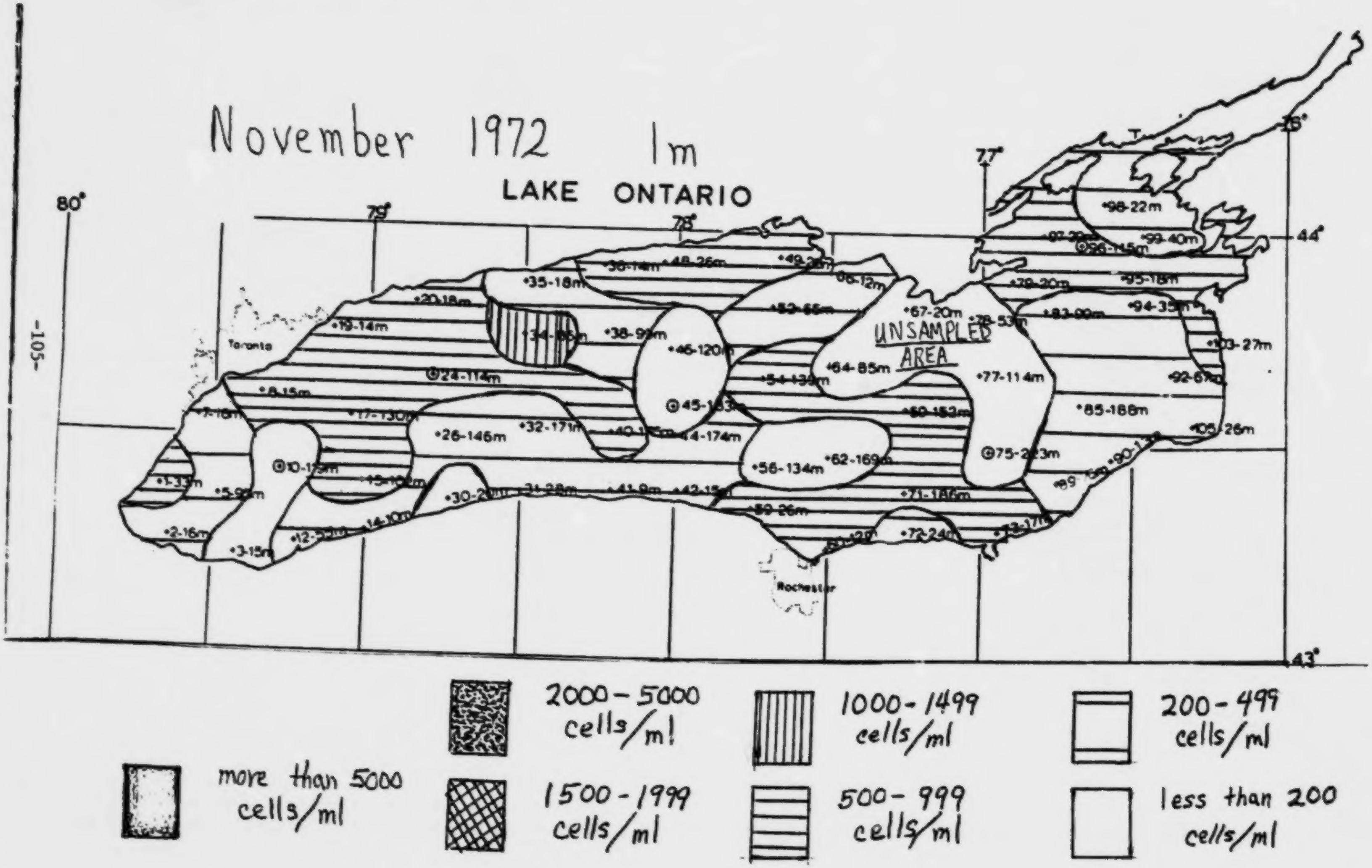

November 1972 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
UNSAMPLED AREA
•98-22m
•99-40m
•95-18m
•94-35m
•103-27m
•92-67m
•105-26m
•85-188m
•83-99m
•79-20m
•77-114m
⊙75-223m
•72-24m
•71-186m
•67-20m
•64-85m
•62-169m
•56-134m
•54-139m
•53-65m
•50-26m
•48-26m
•46-120m
⊙45-183m
•44-174m
•42-15m
•41-9m
•38-99m
•36-14m
•35-18m
•34-85m
•32-171m
•31-28m
•30-20m
•26-146m
⊙24-114m
•20-18m
•19-14m
•17-130m
•15-102m
•14-10m
•12-53m
⊙10-119m
•8-15m
•7-18m
•5-99m
•3-15m
•2-16m
•1-33m
more than 5000 cells/ml
2000-5000 cells/ml
1500-1999 cells/ml
1000-1499 cells/ml
500-999 cells/ml
200-499 cells/ml
less than 200 cells/ml

Figure 7. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during February 1973 cruise. Stations nor sampled are circled.

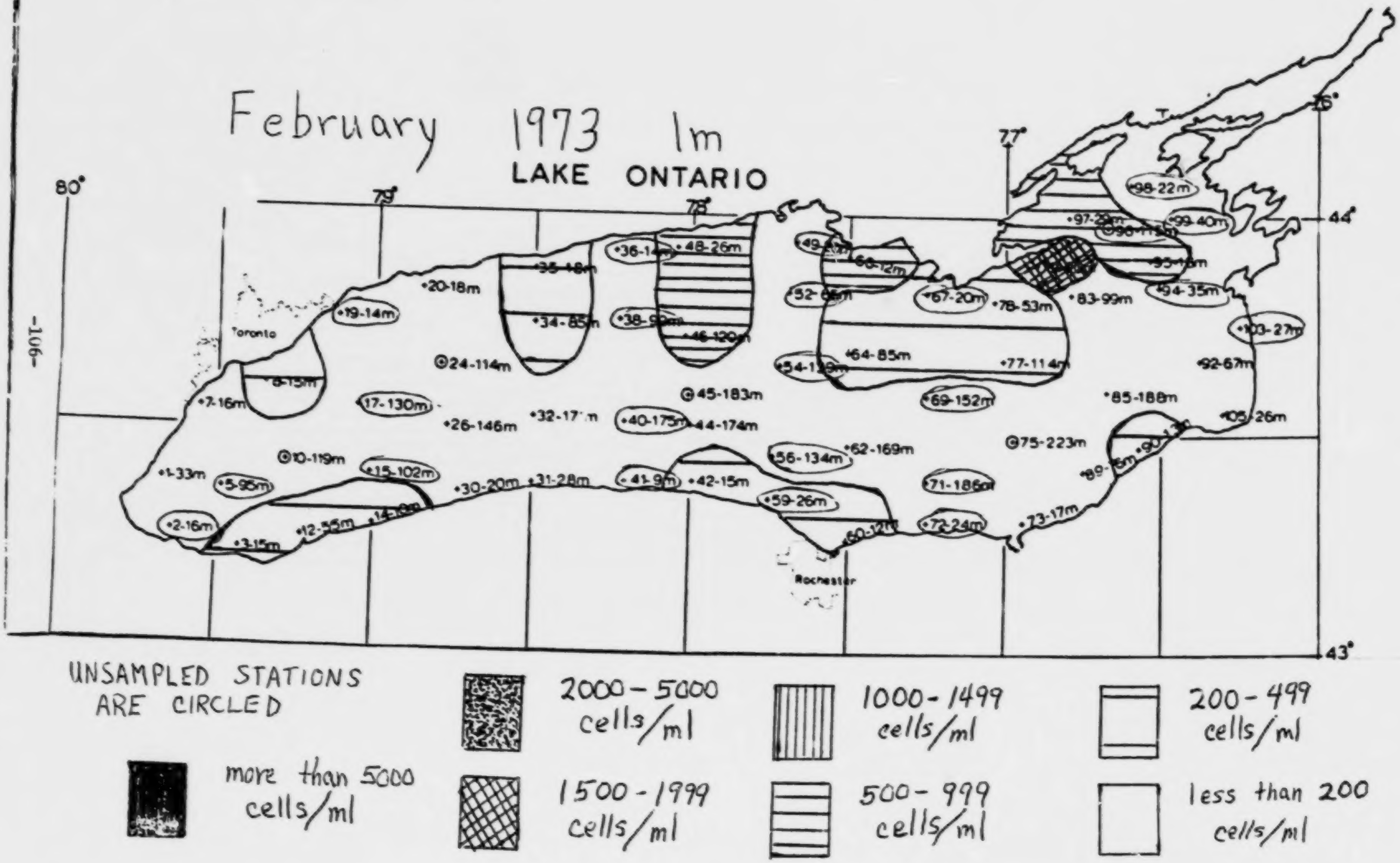

February 1973 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
•1-33m
•2-16m
•3-15m
•5-95m
•7-16m
•8-15m
⊙10-119m
•12-55m
•15-102m
•17-130m
•19-14m
•20-18m
⊙24-114m
•26-146m
•30-20m
•31-28m
•34-85m
•35-18m
•38-99m
•40-175m
•41-9m
•42-15m
•44-174m
⊙45-183m
•46-120m
•48-26m
•52-66m
•54-129m
•56-134m
•59-26m
•62-169m
•64-85m
•67-20m
•69-152m
•71-186m
•72-24m
•73-17m
⊙75-223m
•77-114m
•78-53m
•83-99m
•85-188m
•92-67m
•94-35m
•97-29m
•98-22m
•99-40m
•103-27m
•105-26m
UNSAMPLED STATIONS ARE CIRCLED
more than 5000 cells/ml
2000 - 5000 cells/ml
1500 - 1999 cells/ml
1000 - 1499 cells/ml
500 - 999 cells/ml
200 - 499 cells/ml
less than 200 cells/ml

Figure 8. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during March 1973 cruise. Stations not sampled are circled.

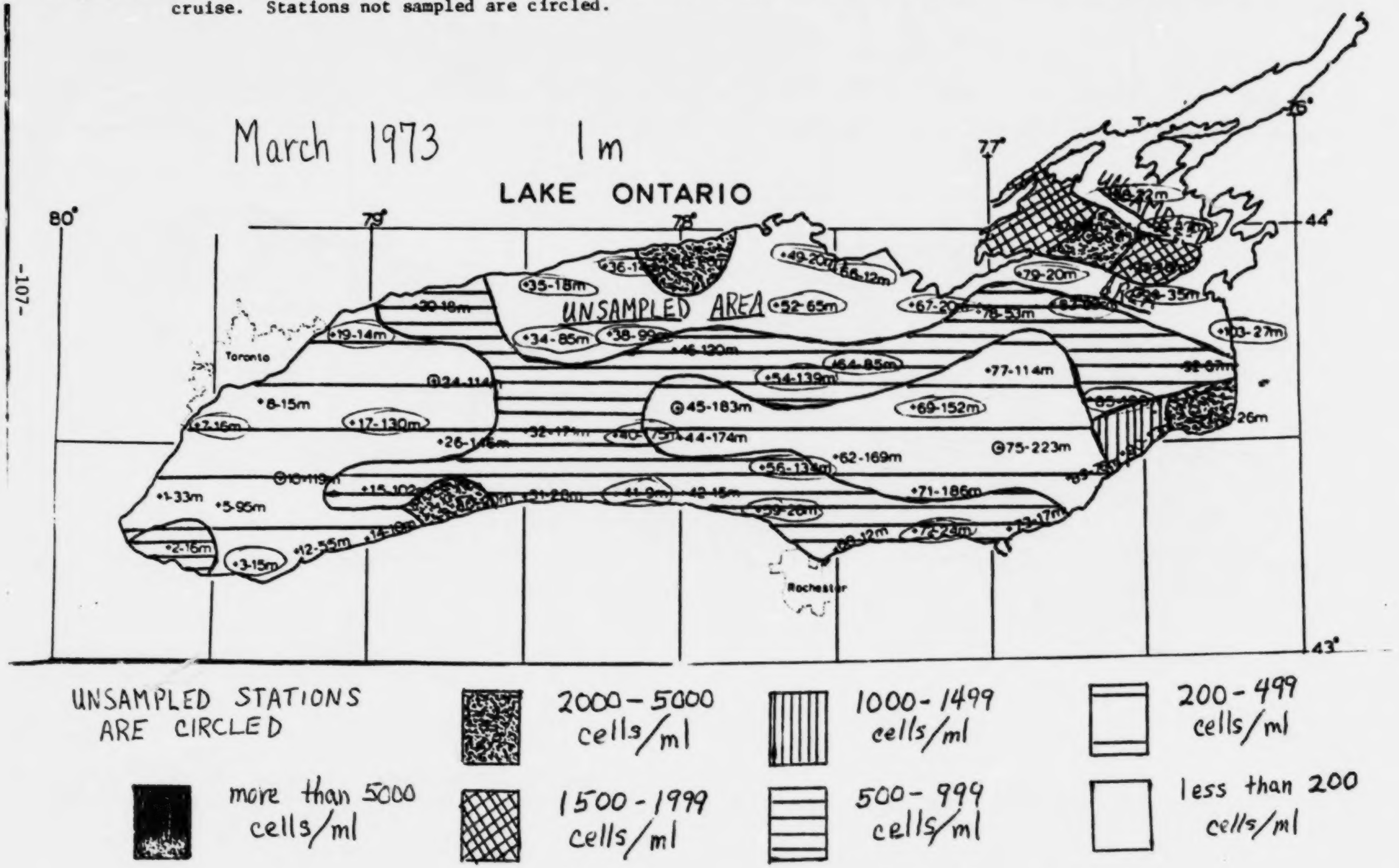

March 1973
1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
UNSAMPLED AREA
•1-33m
•2-16m
•3-15m
•5-95m
•7-16m
•8-15m
•12-55m
•15-102m
•17-130m
•19-14m
•26-146m
•30-18m
•34-85m
•35-18m
•38-99m
•44-174m
⊙45-183m
•46-120m
•49-20m
•52-65m
•54-139m
•56-138m
•62-169m
•64-85m
•69-152m
•71-186m
⊙75-223m
•77-114m
•78-53m
•79-20m
•103-27m
26m
UNSAMPLED STATIONS
ARE CIRCLED
more than 5000 cells/ml
2000–5000 cells/ml
1500-1999 cells/ml
1000-1499 cells/ml
500-999 cells/ml
200-499 cells/ml
less than 200 cells/ml

Figure 9. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during April 1973 cruise. Stations not sampled are circled.

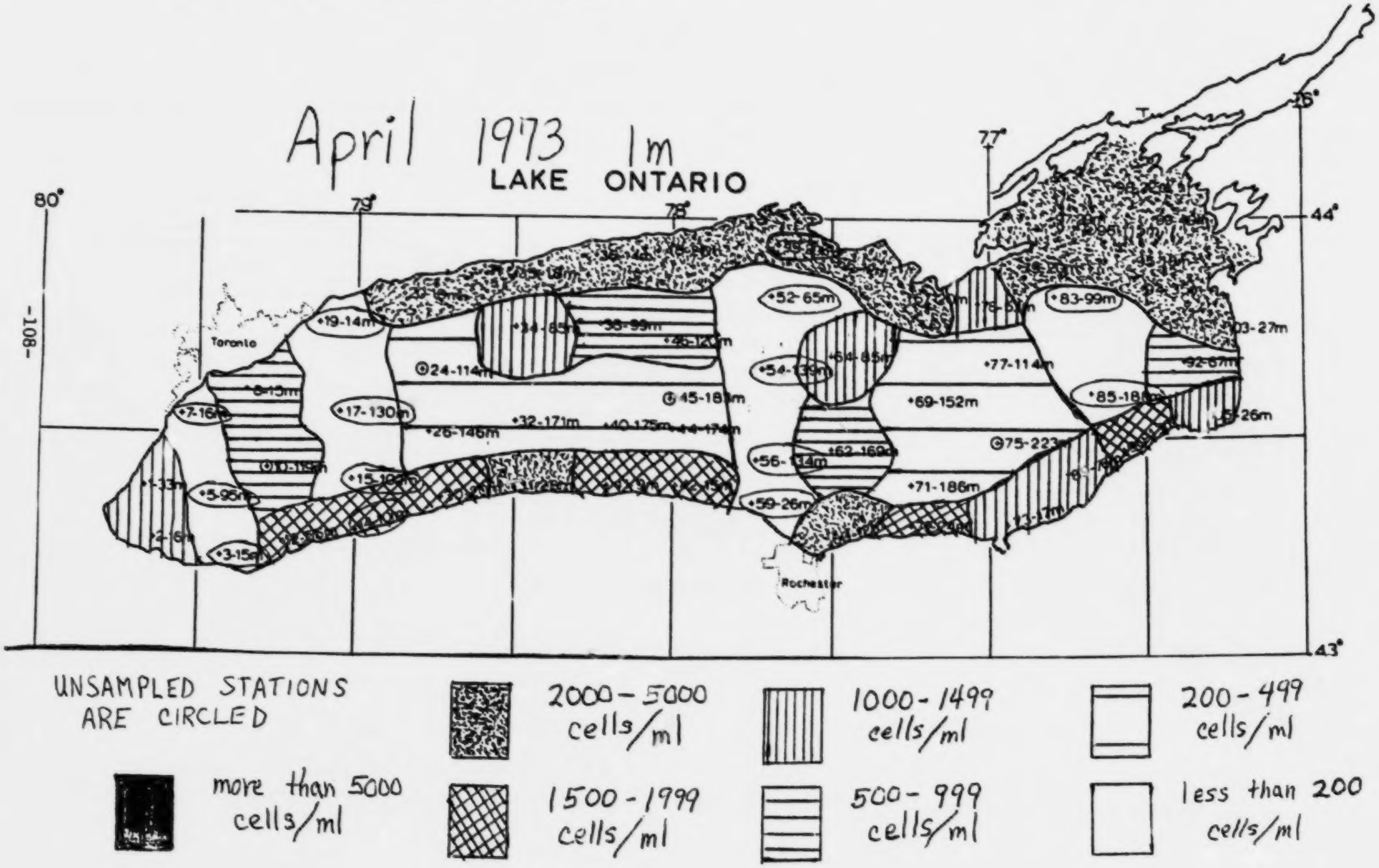
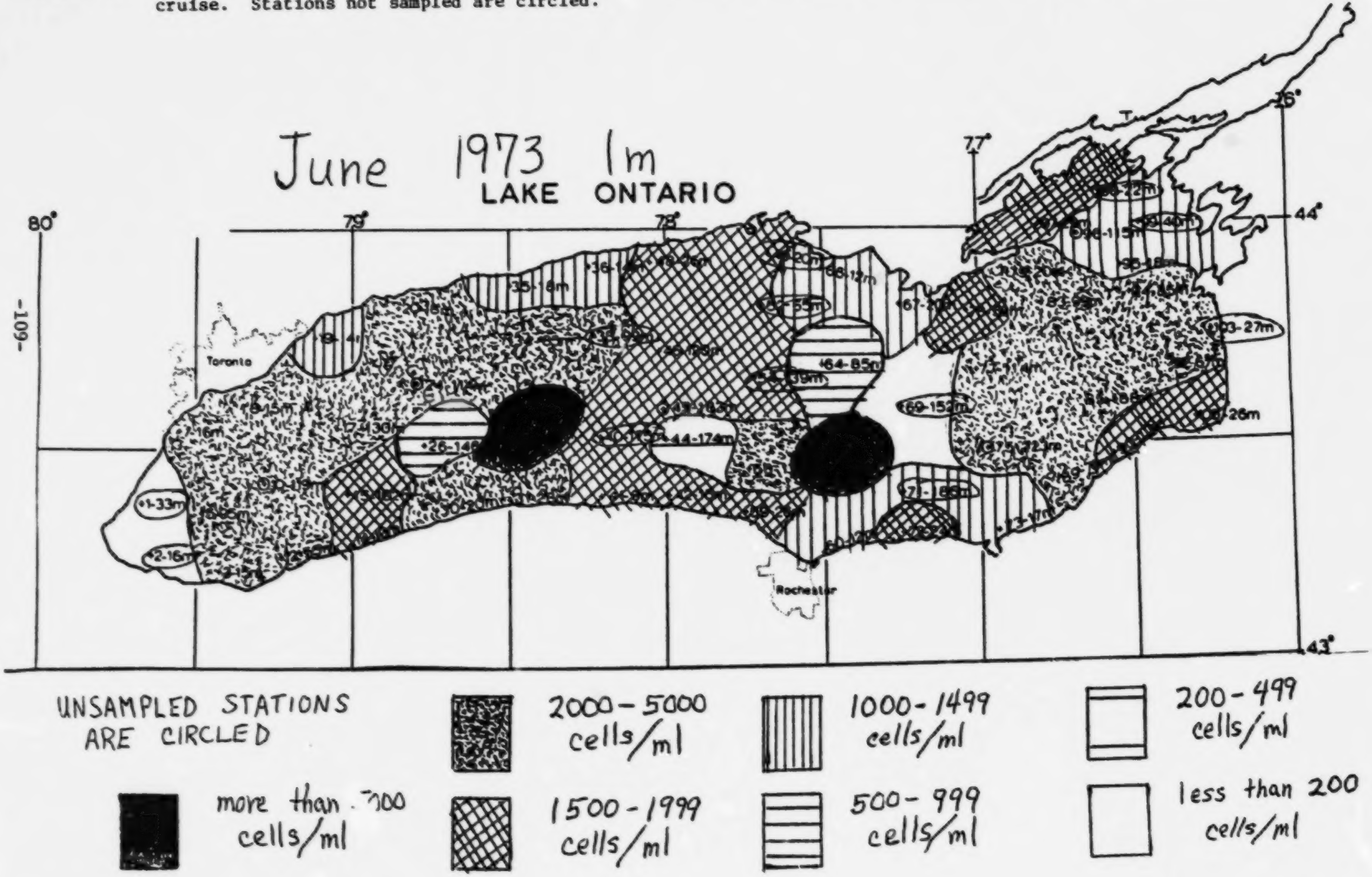

April 1973 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
•19-14m
•8-13m
•7-16m
•1-33m
•5-95m
•2-16m
•3-15m
•17-130m
•15-100m
⊙24-114m
•26-146m
•34-85m
•38-99m
•32-171m
•40-175m
•44-174m
•46-120m
⊙45-183m
•52-65m
•54-139m
•56-134m
•59-26m
•64-85m
•62-169m
•69-152m
•71-186m
•76-37m
•77-114m
⊙75-223m
•83-99m
•85-180m
•92-67m
•93-27m
•95-26m
UNSAMPLED STATIONS ARE CIRCLED
more than 5000 cells/ml
2000-5000 cells/ml
1500-1999 cells/ml
1000-1499 cells/ml
500-999 cells/ml
200-499 cells/ml
less than 200 cells/ml

Figure 10. Distribution of total phytoplankton abundance in near surface waters of Lake Ontario during June 1973 cruise. Stations not sampled are circled.


June 1973 1m
LAKE ONTARIO
80°
79°
78°
77°
76°
44°
43°
Toronto
Rochester
UNSAMPLED STATIONS ARE CIRCLED
more than 5000 cells/ml
2000 - 5000 cells/ml
1500 - 1999 cells/ml
1000 - 1499 cells/ml
500 - 999 cells/ml
200 - 499 cells/ml
less than 200 cells/ml

ANNUAL REPORT

EXPLORATION OF HALOGENATED AND RELATED HAZARDOUS CHEMICALS IN LAKE ONTARIO

Grant Number 800608

April 1, 1972 to March 31, 1973

G. Fred Lee and Clarence L. Haile
Environmental Chemistry
Department of Civil Engineering
Texas A&M University
College Station, Texas 77843

1. Project Objectives

The early explorations of pesticides in the Great Lakes with gas chromatographic techniques revealed that chlorinated pesticides such as DDE are present in the fish from several lakes at concentrations greater than those which are thought to be safe for higher organisms and man. The use of more sophisticated analytical instrumentation such as mass spectrometry has led to the identification of trace amounts of many other potentially toxic organic chemicals, and the likelihood that the food resources of the Great Lakes are being jeopardized by current industrial, municipal, and agricultural practices is suggested. Veith (1970) confirmed the presence of chlorobiphenyls (PCBs) in Lake Michigan fish at levels exceeding the action limit established by the Food and Drug Administration. Zabek (1970) found pentachloronaphthalenes eluting simultaneously with DDE from the gas chromatograph in the analysis of Great Lakes

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*This project is also conducted at the University of Wisconsin, Madison, Wisconsin.

fish. Stalling (1971) has reported the presence of phthalate esters (industrial plasticizers) in several aquatic environments.

In addition to these groups of chemicals, which are commonly detected with routine analytical techniques, the presence of still other toxic chemicals at levels below normal detection limits have been confirmed with the gas chromatograph/mass spectrometer after careful pre-column concentration steps. The chemicals generating the major concern are the chlorodibenzo-p-dioxins which may be trace contaminants in chlorophenol formulations (U.S. Senate, 1970) and the chlorodibenzofurans which may be trace contaminants or derived from PCB formulations (Vos and Koeman, 1970; Vos, Koeman _et al._, 1970). Both of these classes of chemicals produce teratogenic effects at levels below one microgram/gram. Furthermore, these chemicals may be responsible for many of the effects commonly attributed to pesticides which mask the presence of the dioxins or furans because of their greater relative concentrations.

The objectives of this study are to:

1. collect fish, water, sediment, benthos, plankton, and _Cladophora_ from four regions of Lake Ontario and to
2. isolate and identify the major and minor trace halogenated and related potential hazardous chemicals in the Lake Ontario ecosystem through the use of gas chromatography and gas chromatography/mass spectrometry.

This study will provide complete chemical characterization of trace contaminants in the Lake Ontario ecosystem with special emphasis on the possible presence of hazardous chemicals such as the chlorinateddibenzo-p-dioxins and chlorinated dibenzofurans which have been detected in industrial chemicals. The results of this study will provide baseline information concerning the major contaminants and may serve as an early warning of hazardous chemicals heretofore undetected by routine monitoring programs.

2. Planned Operation Versus Actual Operation

There has been no deviation from the original objectives with the exception of a slightly expanded sampling program in order to obtain more complete data from the lake system and to gain information concerning halogenated organic inputs for the lake. Thus fish, water, sediment, and plankton samples have been collected from more than four lake regions. Also, fish and water sampling is planned for the major rivers feeding Lake Ontario.

3. Cost to Program Because of Study Deviations

The expansion of our sampling program has not increased the project costs since these samples were collected in conjunction with the initially planned sampling. The extraction, extract clean up, and analysis of these extra samples has thus far not contributed appreciable cost nor consumed significantly more than that for the originally projected sample load. It is felt that this increased sampling program will contribute much toward achieving the overall objectives of the study without making excessive demands on manpower or resources.

4. Status of Program

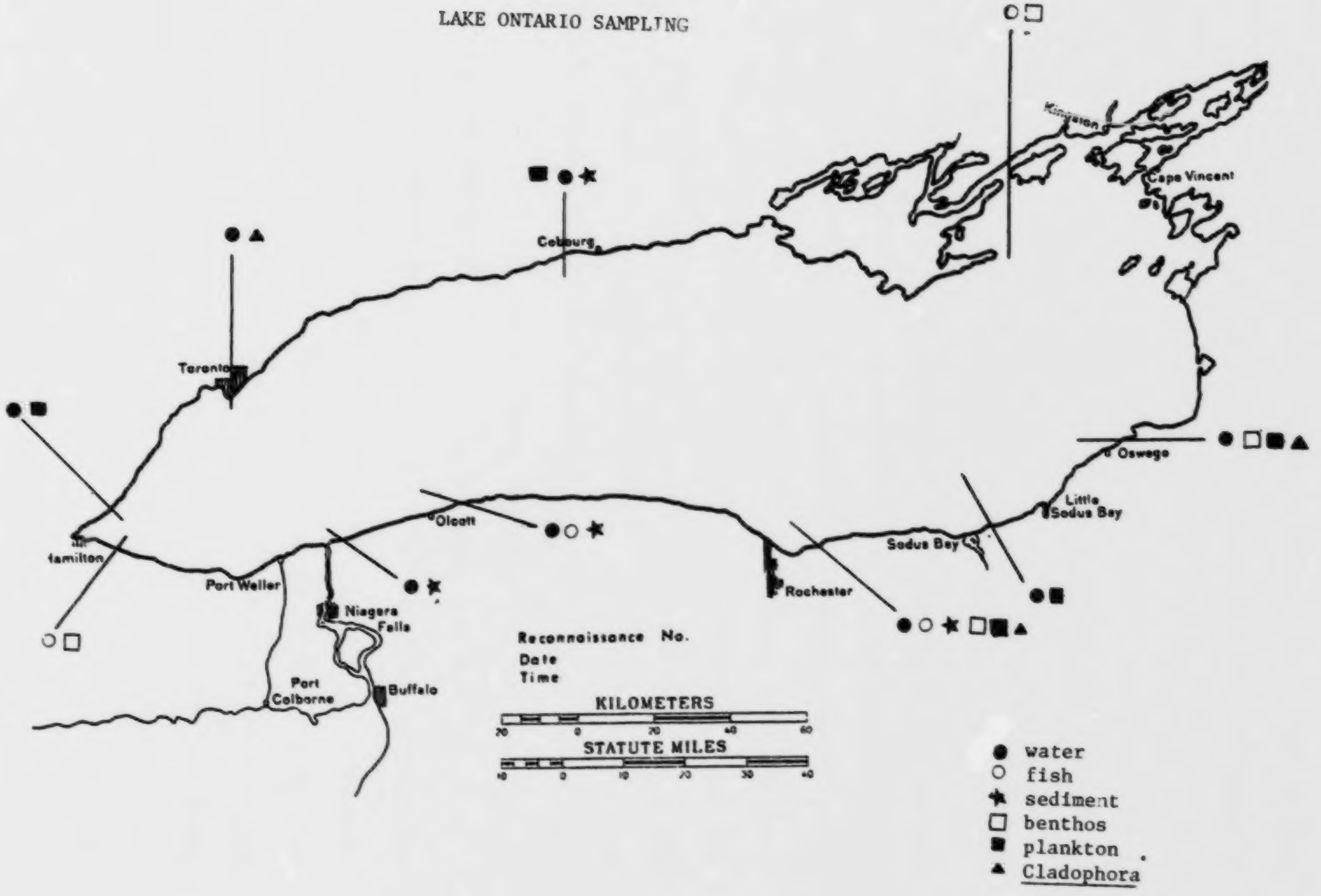
Sampling

The major effort for this year's work was devoted to sample collection, extraction, and extract clean up in preparation for the gas chromatographic analysis to follow. Fish, water, benthos, sediment, net plankton, and Cladophora samples were collected from various areas of the lake but the most extensive sampling was conducted in the near shore waters off Rochester, Oswego, and Hamilton with lesser sampling off Olcott, Cobourg, and at the extreme eastern end of the lake. Figure 1 shows the regions from which these lake system samples were taken.

Water samples were usually taken at 1/2 m and 10 m depths in addition to 10 m above the sediment at each station, Cladophora was gathered at 1-2 m depths, plankton netted at depths of 5 - 10 m, and fish were trawl netted at 10 - 40 fathoms. Sediment was sampled by dredging and benthos was collected by an epibenthic sled. All samples were transported frozen or very cold to minimize decomposition.

FIGURE I

LAKE ONTARIO SAMPLING


Kingston
Cape Vincent
Cobourg
Toronto
Hamilton
Port Weller
Niagara Falls
Port Colborne
Buffalo
Olcott
Rochester
Sodus Bay
Little Sodus Bay
Oswego
Reconnaissance No.
Date
Time
KILOMETERS
20 0 20 40 60
STATUTE MILES
10 0 10 20 30 40
● water
○ fish
★ sediment
☐ benthos
■ plankton
▲ Cladophora

Sample Processing

Water

Each water sample was extracted at the collection site by passage through a column of six polyurethane foam plugs at a flow rate of 250 ml/min. The plugs had been previously exhaustively extracted with hexane-ethyl ether azeotrope to remove contaminants before coating with a 1% solution of silicone oil (DC-200) in hexane and then air dried. Following the water extraction, the plugs were removed from the column, the column rinsed with acetone, and the plugs again exhaustively extracted with hexane-ether (column washings were added to the extract). The extracts were reduced to about 5 ml before placing on an 8 g column of a florisil (Fisher F-100, 60 - 100 mesh, washed with hexane and activated by heating to 650°C for 2 hr). The samples were eluded with 25 ml of 6% ether in hexane before changing receivers and eluding with 50 ml 12% ether in hexane. The receiving flasks were changed again and the columns stripped with 50 ml ether. All three fractions were reduced to 10 ml and then diluted to 25 ml for storage (freezing) awaiting later GC analysis. In the first fraction are PCBs and many chlorinated hydrocarbon pesticides, the second fraction contains the phthalate esters, and the final fraction contains those compounds more polar than the phthalate esters.

Fish

The whole fish samples were extracted and the extracts cleaned up by liquid chromatography after Veith (1970). After grinding the frozen fish twice to homogenize the flesh, six 10 g sub-samples of flesh were weighed out for each specie collected from each sampling site. Generally only three species were taken at each site: alewife, smelt, and sculpin. Each 10 g sample was thoroughly mixed with 70 g anhydrous sodium sulfate and placed in an all glass thimble for extraction. The sample was extracted (Soxhlet) for at least 3 hours with 170 ml of a 1:1 ethyl ether-hexane mixture (v/v). The resulting extract was concentrated by evaporation to about 10 ml before diluting to 20 ml with hexane and removing a 2 ml aliquot for fat analysis (weight of residue after evaporation at 150°C for 20 min). The remaining extract was placed on a 20 g column of florisil topped with a little anhydrous sodium sulfate. The sample was eluded with 20 ml of 6% ether in hexane, the receiver was changed before further elution was 200 ml of 12% ether in hexane, and the receiving flask changed again before final elution with 300 ml of 50% ether in hexane. The first fraction contains the PCBs and many chlorinated hydrocarbon pesticides, the second holds the phthalate esters, and the final fraction contains those compounds more polar than the phthalate esters.

The pesticide fraction was concentrated and then diluted to 50 ml before removing a 5 ml aliquot for preliminary GC analysis of DDE (DDE is generally the most prominant peak on the chromatogram). The remainder of the pesticide fraction was concentrated to less than 10 ml before placing it on a 20 g column of silicic acid, partially deactivated with 2.1% water. Elution with 250 ml hexane and eludent concentration to 25 ml produced the PCB fraction for GC analysis. Further elution with 200 ml of 3:1 dichloromethane-hexane (v/v) and concentration to 25 ml produced the pesticide fraction for GC analysis.

Sediment

Kept frozen or cold until processed, portions of the samples were allowed to air dry at room temperature before weighing out six 25 g sub-samples for analysis. The 25 g samples were thoroughly ground (mortar and pestle), mixed with anhydrous sodium sulfate, and extracted in a large Soxhlet extractor (glass thimble) with 170 ml 1:1 hexane-ether for four hours. The extracts were concentrated to about 10 ml before cleaning up by liquid chromatography of florisil and silicic acid utilizing the same procedures as for the fish samples described above.

Benthos

Benthic fauna samples were also kept frozen or very cold until processed. After drying at room temperature, at least three 10 g sub-samples were weighed out for each sample. There was no attempt to segregate species. These sub-samples were then extracted and cleaned up according to the procedures outlined above for sediment samples.

Plankton

The frozen plankton samples were allowed to air dry at room temperature before transferring to tared centrifuge tubes. The samples were centrifuged at 2000 rpm for 25 minutes. After rapidly decanting the supernatant into a separatory funnel, 2 ml acetone was added to the tubes and the samples allowed to air dry. The tubes were weighed to determine sample weight. The water decanted from each tube was extracted twice with 25 ml portions of hexane to recover organics released from the cells. About 35 ml of these hexane extracts were added to the corresponding sample tubes and the tubes shaken periodically over a 36 hour period. The extracts were then decanted and the extraction process repeated with 35 ml portions of fresh hexane. The extracts were concentrated to about 5 ml before placing on 8 g florisil columns and cleaning up utilizing procedures outlined above for water samples.

Cladophora

Cladophora samples from the south shore of Lake Ontario were extracted and cleaned up as with the net plankton samples with the exception that sample size was sufficient so that the samples could be subdivided. The number of subsamples varied from three to six.

Sample Analysis

Areas of sample analysis completed thus far are fats analysis and p,p'-DDE analysis on the lake fish samples. The fat data was obtained from the residue weight after drying an aliquot of crude whole fish extract at 150°C for 20 minutes. Since p,p'-DDE is generally the largest peak in the gas chromatogram, the fish samples were subjected to initial screening for p,p'-DDE by GC. A five foot coiled glass column of 3% DC-200 coated on 80/100 Chromasorb W was used in conjunction with the tritium foil electron capture detector on a Varian Aerograph 1700 GC. The column, detector, and injector temperatures were 200°C, 210°C, and 225°C, respectively. The carrier gas was purified nitrogen at 41 pounds/square inch. This preliminary screening not only gives initial data input, but also provides a good overview of sample composition in order to facilitate the more complete analysis to follow.

Progress has been made in determining optimum gas chromatographic columns and column conditions for the bulk of the GC analyses to follow. Several columns utilizing liquid phases such as OV-1, DC-200, OV-17, and mixed liquid phases such as OV-17/QF-1, DC-200/QF-1, and OV-1/QF-1 coated on 80/100 mesh Gas-Chrom Q, 100/120 mesh Gas-Chrom Q, or 100/120 mesh Chromasorb G packed in 2 mm ID coiled glass columns 5 - 7 feet in length were prepared and evaluated using standard pesticide solutions, pesticide cocktail solutions, and some Lake Ontario fish extracts. Columns showing high potential for separation with reasonable retention times include those prepared with DC-200, OV-17, OV-17/QF-1, and OV-1/QF-1. Column temperatures of 160-200°C were utilized with carrier gas flows of 7 - 35 ml/min.

5. Areas of Program Which Are Behind Schedule

Although progress has been fairly smooth, it is felt that our sample analysis should be at a slightly more advanced stage. The primary reason for delay has been the absence of Clarence L. Haile, graduate student working with the project. Mr. Haile was engaged in the service of the U.S. Army for a 90 day period, necessitating his absence from January 10 to April 16, 1973. It is foreseen, however, that this will cause no delay in the final project completion, nor will it disallow the full achievement of the project objectives.

6. Summary of Results to Date

Since the major portion of this year's work has been directed toward preparing for the bulk of the analyses, only a small amount of data has been obtained. Fats analysis and preliminary p,p'-DDE data have been determined. Table I shows the resultant percentage of fats from the Lake Ontario fish sampled. These values are quite within the expected range. Table II shows preliminary p,p'-DDE data for the lake fish. These values are also not unusual. It should be emphasized that these are preliminary DDE values and were evolved in conjunction with extract screening to obtain a broad overview of extract content.

TABLE I

FISH FAT CONTENT
(in %)

Location	Species		
	Smelt	Alewife	Sculpin
Hamilton	4.85	3.59	9.78
Olcott*	2.99	5.17	5.10
Rochester	4.12	3.38	4.30
Mexico Bay	----	3.14	5.68
Galloo-Stony	5.95	2.38	8.61
Prince Edward Point	6.71	1.18	7.57

*Three Spine Stikleback has 1.61% fats.

TABLE II

P,P'-DDE IN FISH
(ug/g)

Location	Species		
	Smelt	Alewife	Sculpin
Hamilton	1.33	0.44	0.94
Olcott*	0.83	0.74	0.98
Rochester	1.30	0.67	1.06
Mexico Bay	----	0.76	1.28
Galloo-Stony	0.91	0.92	0.57
Prince Edward Point	0.82	0.81	0.80

*Three Spine Stikleback had 0.71 ug/g DDE.

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Progress Report

PHOSPHORUS UPTAKE AND RELEASE BY LAKE ONTARIO SEDIMENTS (IFYGL)

Grant Number 800609

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Project Objectives:

1) To determine the forms, amounts and mobility of phosphorus in sediment cores from Lake Ontario.

2) To determine the rate and extent of phosphorus movement in sediment cores as a function of sediment properties and environmental conditions.

3) To predict the release and uptake of phosphorus by Lake Ontario sediments as a function of sediment properties and conditions in the overlying water.

Research Approach:

Sediment cores were obtained and sectioned to allow evaluation of the characteristics of the surface sediments. Measurements were made of the forms and mobility of sediment phosphorus. Intact cores were transported to the laboratory for measurement of P release under controlled conditions. Subsequent sampling will emphasize separating interstitial water *in situ* for subsequent phosphorus and iron determinations.

Sampling:

Sediment cores (7 cm diameter) were obtained with a Benthos gravity corer. Cores were sectioned at 5 cm intervals and transported to the lab for analysis. Major emphasis was on the surface 5 cm layer, but some measurements were made on subsurface layers.

For the initial sampling trip (June 21, 1972), 10 sampling stations were selected to allow comparison of the three major lake basins and the postglacial mud and the glacio-lacustrine clays (Fig. 1). Four cores were taken at each station to allow comparisons of station and interstation variability. General characteristics of these sediments were described in Thomas *et al.* (1972). Based on this classification, stations 83, 75, 92, 45, 32 and 10 were postglacial muds, stations 34 and 52 were near-shore glacio-lacustrine clays, and station 62 was near a between-basin sill of glacio-lacustrine clay.

For the second sampling trip (November 6, 1972), station 30 (located in near-shore silts according to the classification of Thomas *et al.*, 1972) and 60 of the inshore zone were selected in addition to those sampled in June except station 32 and 96 (Fig. 1). Cores were obtained at some stations to provide intact cores for transport to the laboratory and comparison of station and inter-station variability. The surface 5 cm layer of several cores was squeezed *in situ* to obtain interstitial water for dissolved inorganic phosphorus determination.

The third sampling trip (September to October, 1973) will emphasize squeezing different core sections *in situ* and analyzing the interstitial water for phosphorus and iron in the laboratory.

Measurements:

Measurements of the forms and mobility of sediment P were made by procedures described elsewhere (Sommers et al., 1970; Shukla et al., 1971; Williams et al., 1971 a, 1971 b; Li et al., 1972). These measurements included total P, total inorganic P, total organic P, sediment exchangeable inorganic P, interstitial inorganic P, NH_4Cl-P, NaOH-P, CDB-P and HCl-P and the P sorption and desorption characteristics of the sediments. Inorganic P fractionation provides evidence on the chemical mobility of sediment inorganic P (Syers et al., 1973). Interstitial P and NH_4Cl-P are regarded as mobile, while NaOH-P is considered potentially mobile, and CDB-P and HCl-P (apatite) are largely immobile.

During the November sampling trip, a pressure membrane apparatus (Reeburgh, 1967) was used to squeeze interstitial water from several sediment samples on board ship. Interstitial water was also obtained by a centrifugation-filtration technique on samples transported to the laboratory. Sediments were maintained in a nitrogen atmosphere during separation to avoid possible oxidation of Fe and subsequent P sorption. The interstitial inorganic P values for interstitial water separated in situ by the squeezing technique were significantly higher than values for the same sediment samples separated in the laboratory by the centrifuge-filtration technique. An investigation of the two techniques of interstitial water separation is presently in progress. It is believed in situ separation of interstitial water is necessary to minimize storage effects. Measurements of P release from intact cores from the November trip were made under controlled laboratory conditions.

During the third sampling trip (September to October, 1973), the pressure-membrane apparatus will be used to obtain interstitial water on board ship.

Results and Discussion:

A brief discussion of results obtained from the first and second sampling trips is presented. Because data acquisition is incomplete, only tentative interpretation will be made at this time.

Amounts of total P, total inorganic P and total organic P varied between stations for both trips (Tables 1 and 2). Phosphorus values were similar for the same station sampled on both trips. The surface 5 cm layer usually exhibited higher phosphorus values than subsurface layers (Table 2). Amounts of organic P were low especially in the inshore zone stations. The organic P increased in the 15 to 20 cm core section (Table 2).

Differences among stations were more apparent in the forms of inorganic P present than in the amounts of total P or total inorganic or organic P. The inshore zone stations tended to contain small amounts of NaOH-P and CDB-P but a high proportion of HCl-P (Tables 3 and 4). The basin stations contained similar proportions of NaOH-P and HCl-P and small amounts of CDB-P. Apparently, the proportion of immobile P (apatite, extracted by HCl) is high in the inshore zone, while the basin muds contain a high proportion of potentially mobile Fe and Al-bound P (NaOH-P). The proportion of NaOH-P decreased with increasing depth below the sediment surface for station 30. This, along with the drop in sediment water content below 5 cm at station 30 (Table 5), indicates that the surface 5 cm layer was composed of sediments of substantially different composition from the subsurface layers.

Values of sediment exchangeable P were in agreement with the differences in chemical mobility of inorganic P observed between stations based on measurements of inorganic P forms. The inshore stations contained small amounts of exchangeable P relative to the basin stations (Table 6). The basin sediments apparently contain a higher proportion of inorganic P in a form available for interaction with the associated interstitial water. Station 62 exhibited an exchangeable inorganic P level similar to the inshore zone stations rather than the basin stations.

Several factors suggest a possible difference in phosphorus forms for station 62 from those in basin stations. According to a map presented by Thomas _et_ _al_. (1972), station 62 lies close to the Scotch Bonnet sill which is composed of glacio-lacustrine clay, while the major basins are predominately postglacial muds (Thomas _et_ _al_., 1972). The sediment water content at station 62 was lower than observed in most cases for the basin stations (Table 5). Furthermore, the proportion of NaOH-P was lower at station 62 than for basin stations (Table 4). The above evidence suggests that station 62 sediment is different in composition from the basin stations and is more closely related to the inshore zone stations.

Interstitial inorganic P values are currently under investigation and a complete set of data cannot be presented. However, initial data indicate the interstitial inorganic P values to be higher than the dissolved inorganic P values in the overlying water column. This suggests a potential exists, due to the concentration gradient, for release of dissolved inorganic P to the overlying water. Relatedly, a net transport of P from the water to the sediment likely occurs through deposition of particulate P.

The amount of dissolved inorganic P observed after equilibration of suspensions of Lake Ontario sediments varied from station to station and usually decreased with depth below the sediment surface (Table 7).

Further investigation of inorganic P desorption is planned. The data obtained suggest that Ontario sediments contain sufficient loosely bound inorganic P to maintain a dissolved inorganic P value higher than that of the lake water.

Sorption of added inorganic P was investigated to determine the ability of sediments to remove inorganic P from water at concentrations in the range of those expected for lake or interstitial waters. In most cases, the inshore zone sediments sorbed less added inorganic P than the major basin sediments (Tables 8 and 9). Station 30 was the exception for the inshore zone and station 62 was the exception for the major basins. These stations have been discussed previously as possibly differing in composition from their respective areas of the lake. Little change in sorption ability with depth below the sediment surface was observed (Table 8). At levels of inorganic P expected in the interstitial water and bottom lake water, the major basin sediments sorbed most of the added inorganic P. However, the amounts remaining in solution were in the range of soluble phosphate concentrations in the water column of Lake Ontario (Shiomi and Chawla, 1970).

Dissolved inorganic P released from intact cores incubated at 8° C in an air or nitrogen system ranged up to 35 ug/1 after a 70-day period. At present, insufficient information is available to estimate rates of release.

The preliminary results obtained indicate that Lake Ontario sediments contain varying amounts of mobile and potentially mobile inorganic P, and that a tendency exists for the release of dissolved inorganic P from the sediment. Major differences exist between the inshore zone sediments and major basin sediments. Subsequent research during the remainder of 1973-74 will emphasize the investigation of the amounts of mobile phosphorus in the sediment and the ability of the sediment to maintain the existing levels of mobile phosphorus. This data combined with previous data will be used to estimate the potential impact of Lake Ontario sediments on the phosphorus status of the lake water.

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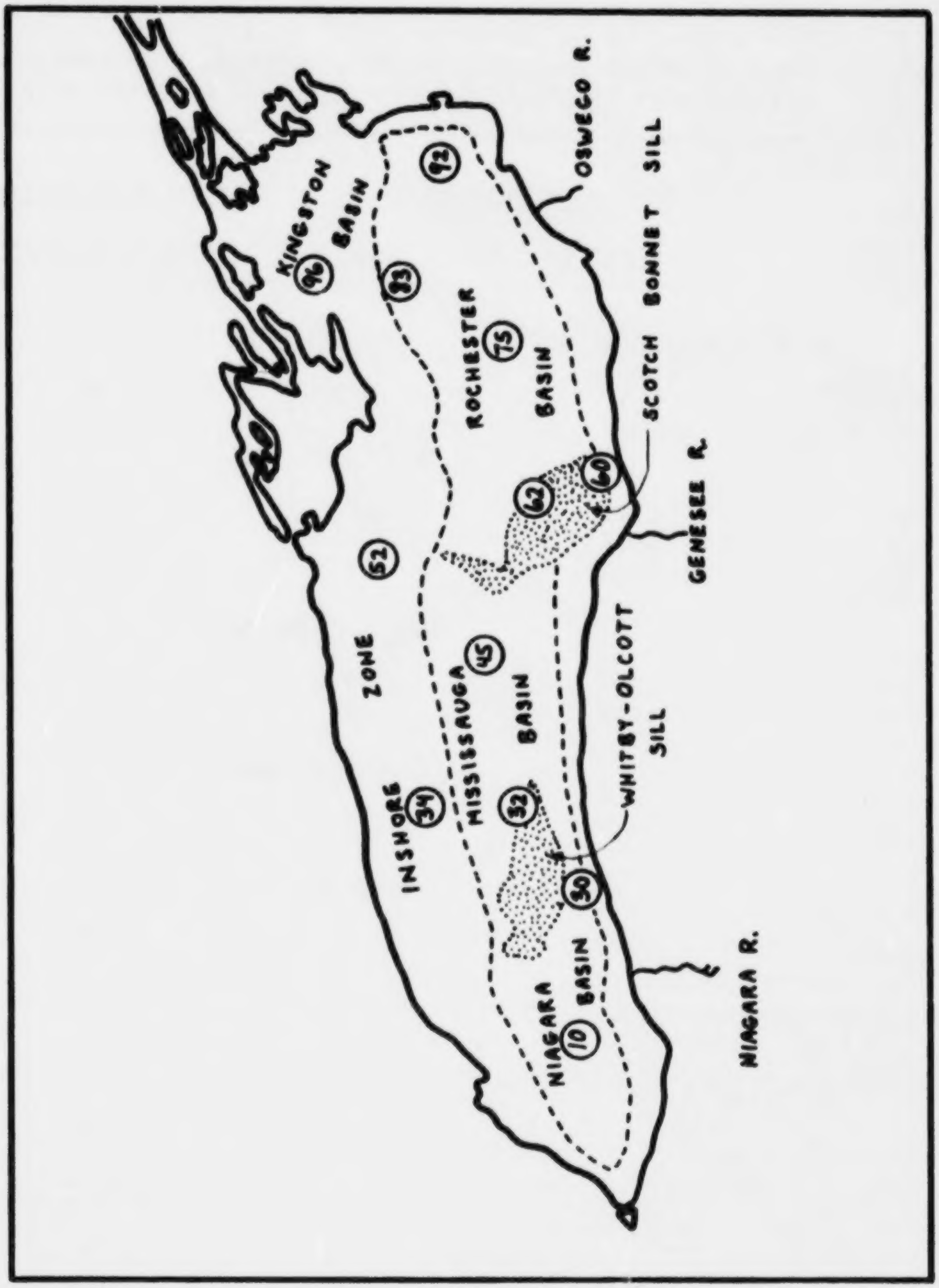
KINGSTON BASIN
96
93
92
OSWEGO R.
SCOTCH BONNET SILL
ROCHESTER BASIN
75
62
60
GENESEE R.
52
INSHORE ZONE
34
MISSISSAUGA BASIN
45
32
30
WHITBY-OLCOTT SILL
NIAGARA BASIN
10
NIAGARA R.

Figure 1 (Thomas et al., 1972)

Table 1 Total P, Total Inorganic P, Total Organic P in Lake Ontario Core Samples from June 21, 1972 Sampling Trip

Sampling Station	Sediment Phosphorus for 0 to 5 cm Core Section		
	Total P	Total Inorganic P	Total Organic P
	ug/g		
		Inshore Zone	
52	945	891	54
		Rochester Basin	
92	1146	1000	146
83	1058	867	191
75	1013	872	141
		Mississauga Basin	
32	1233	995	239
45	1442	1176	266
		Niagara Basin	
10	1431	1229	201
		Kingston Basin	
96	982	810	172

Table 2 Total P, Total Inorganic P and Total Organic P at Various Sediment Depths in Lake Ontario Cores from the November 6, 1972 Sampling Trip

Sampling Station	Total P				Total Inorganic P				Total Organic P			
	0-5[1]	5-10	10-15	15-20	0-5	5-10	10-15	15-20	0-5	5-10	10-15	15-20
	ug/g											
					Inshore Zone							
34	955	890	900	1010	940	890	900	885	15	0	0	125
30	888	685	610	612	790	675	600	550	98	10	10	62
60	548	500	500	567	548	500	500	522	22	0	0	45
					Rochester Basin							
92	1270	966			1140	860			130	100		
62	950	980			810	945			140	35		
75	1163	1103			1050	1020			113	83		
					Mississauga Basin							
45	1310	1028			1065	833			245	195		
					Niagara Basin							
10	1448	1108	1335	1182	1218	935	1132	895	230	173	202	287

---

[1] Sediment depth in centimeters.

Table 3 Ratio of P in NaOH, CDB and HCl Fraction to Total Inorganic P in Lake Ontario Core Sample from June 21, 1972 Sampling Trip

Sampling Station	Ratio of P Values for the 0 to 5 cm Sediment Layer		
	$NaOH/P_i$[1]	CDB/P_i	HCl/P_i
		%	
		Inshore Zone	
34	2	6	91
52	4	5	90
		Rochester Basin	
83	30	17	48
92	33	14	41
75	46	6	42
		Mississauga Basin	
45	60	15	31
32	53	14	42
		Niagara Basin	
10	48	10	32
		Kingston Basin	
96	18	10	72

[1] P_i = Total inorganic phosphorus.

Table 4 Ratio of P in NaOH, CDB and HCl Fraction to Total Inorganic P in Lake Ontario Core Samples from the November 6, 1972 Sampling Trip

Sampling Station	Ratio of P Values at Following Depths Below the Sediment Surface											
	0-5 cm			5-10 cm			10-15 cm			15-20 cm		
	NaOH/P_i[1]	CDB/P_i	HCl/P_i	NaOH/P_i	CDB/P_i	HCl/P_i	NaOH/P_i	CDB/P_i	HCl/P_i	NaOH/P_i	CDB/P_i	HCl/P_i
	%											
Inshore Zone												
30	28	16	53	10	5	72	8	6	82	6	7	88
60	8	6	81	4	2	95	2	4	91	2	4	95
34	3	6	85	2	6	86	2	5	97	2	8	88
Rochester Basin												
62	22	18	57	15	18	65						
92	37	15	36	30	15	50						
75	40	17	29	50	11	32						
Mississauga Basin												
45	46	19	20	45	8	35						
Niagara Basin												
10	50	19	22	51	7	35	50	6	32	58	8	39

---

[1] P_i = Total Inorganic Phosphorus.

Table 5 Sediment Water Content of Lake Ontario Cores from the November 6, 1972 Sampling Trip[1]

Sampling Station	Water Content at Following Depths Below the Sediment Surface			
	0-5 cm	5-10 cm	10-15 cm	15-20 cm
	%			
		Inshore Zone		
34	52	50	48	46
30	50	30	28	26
60	25	24	19	20
		Rochester Basin		
92	56	54		
62	58	42		
75	76	68		
		Mississauga Basin		
45	77	71		
		Niagara Basin		
10	74	71	65	68

---

[1] % water = weight of water divided by weight of water + sediment.

Table 6 Sediment Exchangeable Inorganic P in the 0 to 5 cm Sediment Layer of Lake Ontario Cores from the November 6, 1972 Sampling Trip

Sampling Station	$^{31}P_{soln}$	Sed Exch $^{31}P_i$[1]		Total Exch P_i	
	ug/g	ug/g	%	ug/g	%
		Inshore Zone			
34	2.4	13.3	1	15.7	2
30	0.45	9.0	1	9.45	1
60	1.05	20.3	4	21.3	4
		Rochester Basin			
62	4.1	29.0	4	33.1	4
92	1.5	167.2	15	168.7	15
75	1.2	193.3	18	194.5	18
		Mississauga Basin			
45	0.88	139.6	13	140.4	13
		Niagara Basin			
10	1.2	193.9	16	195.1	16

---

[1] Sed Exch P_i is expressed as percent of inorganic P in sediment phase; Total Exch P_i is expressed as a percent of inorganic P in the sediment and water phases.

Table 7 Dissolved Inorganic P in a 4% Sediment Suspension of Lake Ontario Sediment After a 40 hour Equilibration in Distilled H_2O

Sampling Station	Dissolved Inorganic P Values for 4% Sediment Suspension of Following Core Sections		
	0-5 cm	5-10 cm	10-15 cm
	ug/l		
		Inshore Zone	
34	101	78	42
30	243	41	
60	55	33	
52	107	73	
		Rochester Basin	
92	135	59	
62	172	179	
75	393	255	201
		Mississauga Basin	
45	920	78	
		Niagara Basin	
10	304	72	

Table 8 Sorption of Added Inorganic P by Lake Ontario Sediments From First Sampling Trip[1]

Sampling Station	Core Section	Added P Sorbed (%) for Added P Level (ug of P per g) of			
		2.5	25	250	2500
			Inshore Zone		
34	0-5 cm	80	80	48	20
	5-10 cm	83	72	41	25
52	0-5 cm	73	60	24	17
	5-10 cm	93	78	50	37
	10-15 cm	95	85	57	31
			Rochester Basin		
92	0-5 cm	100	98	82	52
			Mississauga Basin		
32	0-5 cm	100	100	87	57
	5-10 cm	100	100	48	46
	10-15 cm	100	95	89	52

---

[1] Sediment in 4% sediment suspensions where ug/liter = ug/g x 40.

Table 9 Sorption of Added Inorganic P by Lake Ontario Sediments from the 0 to 5 cm Core Sections of the November 6, 1972 Sampling Trip[1]

Sampling Station	Added P Sorbed (%) for Added P Level (ug/g) of				
	6.25	12.5	25	50	100
			Inshore Zone		
34	71	70	65	59	
30	100		98	99	99
60	91		89	75	62
			Rochester Basin		
92	100		98	98	98
62	66		66	53	46
75	93	98	98	98	
			Niagara Basin		
45	98		99	99	99

---

[1] Equilibrations performed with 4% sediment suspension where ug/l = 40 x ug/g.

MATHEMATICAL MODELING
OF
EUTROPHICATION
OF
LARGE LAKES

(EPA Project No. R 800610)

Annual Report - Year #1
April 1, 1972 - March 31, 1973

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July 1973

Environmental Engineering and Science Program

Manhattan College, Bronx N.Y. 10471

-140a-

SUMMARY

The major thrusts of the research effort during the first year were to compile data prior to IFYGL and to develop preliminary models of eutrophication of Lake Ontario. Data were obtained from a variety of sources including STORET, and CCIW, prepared for computer storage and have been displayed in a variety of summaries to aid in the model building process.

The preliminary models constructed during the first year were three in number: (1) a spatially dependent model for a conservative tracer (2) a kinetic interactive model (Lake 1) of three mixed layers representing the epilimnion, hypolimnion and benthos, and (3) a kinetic interactive model of seven vertical layers, Lake 2. Primary effort was devoted to analyses of eutrophication phenomena using the Lake 1 model. This model contains ten interactive systems including phytoplankton and four higher trophic levels and some major aspects of the nitrogen and phosphorous cycles.

The results to date indicate the importance of higher order predation on phytoplankton populations at average grazing rates of 1.2 liters/mg carbon-day at 20°C. Phytoplankton settling velocity and the importance of vertical mixing has been also investigated in detail. Using two zooplankton levels and average sinking rates of 0.05 meters/day, a bimodal distribution of phytoplankton during a year is obtained. The results agree reasonably well with observed chlorophyll a levels averaged over the entire lake. Phosphorous values are also in good agreement whereas nitrogen forms are only approximately in agreement with observed data.

Plans for the second year include expansion of the model to include some horizontal spatial detail and additional interactive variables. A total of 1400 compartments is envisioned for the expanded model.

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Mathematical Modeling of Eutropication
# of Large Lakes

Annual Report
April 1, 1972 - March 31, 1973

I. Subject Review

The purpose of this research is to structure a mathematical modeling framework of the major features of eutrophication in large lakes. Lake Ontario, the subject of intensive field work as part of the International Field Year for the Great Lakes (IFYGL) is used as the problem setting. The overall objectives of the research include:

a) determination of important interactions in lake eutrophication

b) analysis of lake water quality and biological responses to natural and man-made inputs

c) formation of a basis for estimating the direction of change to be expected under remedial environmental control actions

The problems of impairment of the quality of lake systems are magnified for "large lakes", such as the Great Lakes. The size of these lakes is such as to preclude any immediate improvement in quality after control actions are taken. Further, it is much more difficult to obtain reliable data on water quality, biological structure and hydrodynamic circulation, again because of the difficulty of sampling large lake systems. Deep water circulation may be known only in its broad outlines; indeed the general circulation itself may not be adequately known in relation to climatological and hydrological factors. In the biological area, measures of phytoplankton populations such as species composition are usually temporally and spatially dependent and may change rapidly. The degree of such spatial dependence especially in the near-shore boundary layer is especially important since water use interferences (municipal water supply, bathing, etc.) as a result of excessive phytoplankton growth are often related to near-shore uses. Finally, in the physical, chemical and biochemical area, complex forms of nutrients can exist again both temporally and spatially. Sediment chemistry, interaction with upper layers and "thermal bar" effects all play a role in describing the ecosystem of large lakes.

The basic modeling structure consists of sets of deterministic differential equations representing the biological subsystem and chemical-biochemical subsystems. The lake hydrodynamics are externally supplied by other investigators and previous work. The interactions between the biological and chemical subsystems are both linear and non-linear and attempt to reflect the major effects of man made and natural nutrient inputs.

II. Overall Project Plan

The research is planned to be carried out according to the following tasks:

a) Data compilation and preliminary analysis for mathematic modeling purposes

b) Formulation of major sub-model structures such as

    i biological sub-model

    ii chemical-biochemical sub-model

c) Formulation of interactive models using components of (b) above,

d) Sensitivity analysis of model interactions and components,

e) Verification analysis of sub-models and model structure

f) Simulation analysis of selected future environmental controls.

These steps are not necessarily to be carried out sequentially since, for example, verification analyses, formulation and sensitivity analyses are really part of an iterative loop in the construction of a mathematical model.

The project during the first year has generally followed this plan of operation. As the first year of the project progressed, a more detailed modeling strategy was developed and is summarized in Figure 1.

As shown, two parallel paths are being followed. The first part involves examination of the transport and dispersion structure of Lake Ontario and the gathering of data on the lake geomorphology. A conservative tracer model is used for this purpose with some spatial detail provided by a forty segment model. The second modeling path simplifies the spatial dimensions to a horizontally completely mixed lake with vertical layers. The emphasis in the latter models is on the development of preliminary interaction kinetics between various components of each of the sub-models. These models therefore relate directly to tasks b) and c) of the research plan outlined above.

As indicated above, the project has essentially followed the original research plan. Therefore, there has not been any significant deviation in the type of tasks originally laid out although there has been an increased need for additional computational effort in the second year of the study. During the period covered by this annual report however, there was no additional cost to the program above that originally budgeted.

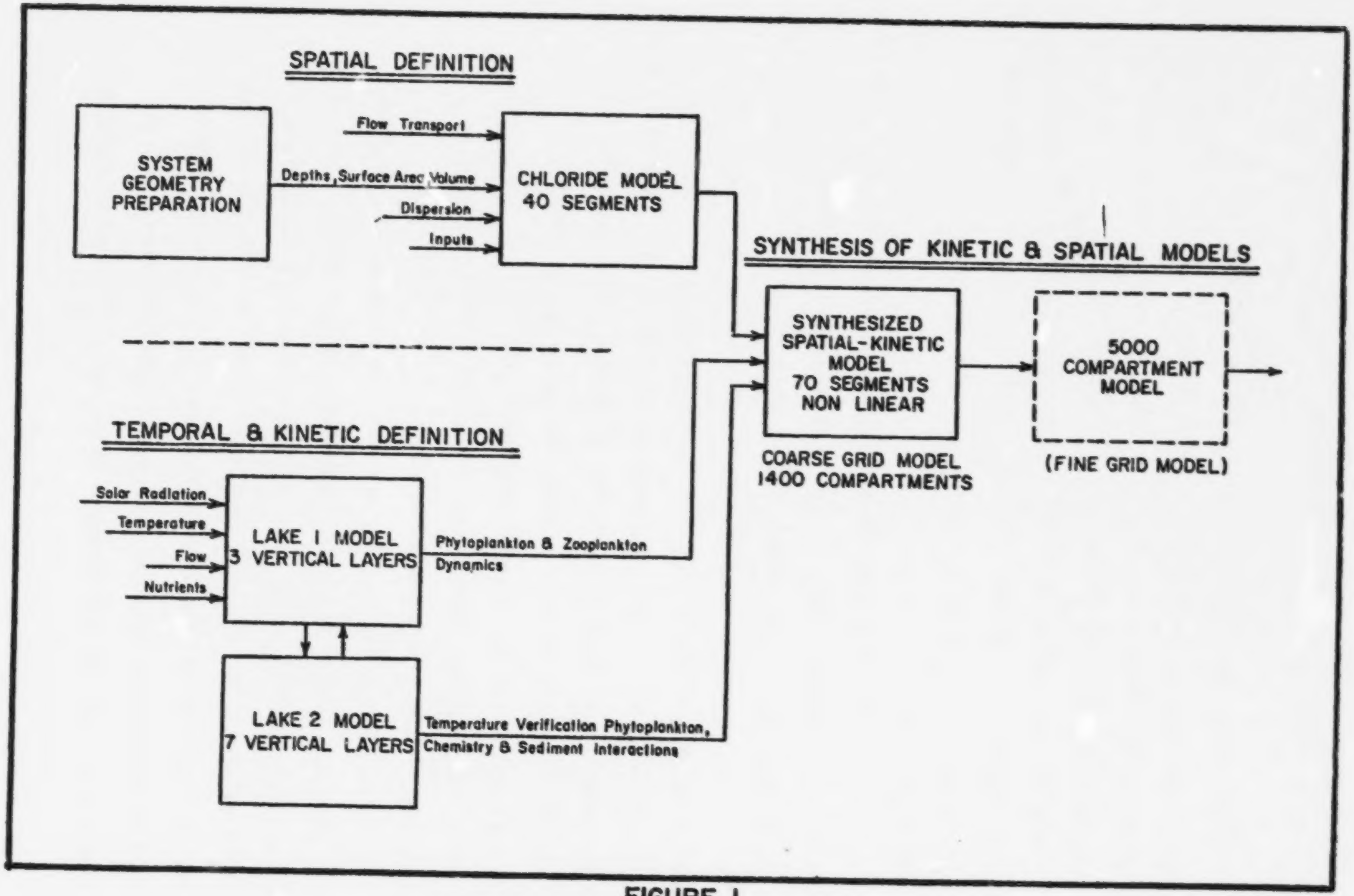
SPATIAL DEFINITION
SYSTEM GEOMETRY PREPARATION
Flow Transport
Depths, Surface Area Volume
Dispersion
Inputs
CHLORIDE MODEL 40 SEGMENTS
SYNTHESIS OF KINETIC & SPATIAL MODELS
SYNTHESIZED SPATIAL-KINETIC MODEL 70 SEGMENTS NON LINEAR
COARSE GRID MODEL 1400 COMPARTMENTS
5000 COMPARTMENT MODEL
(FINE GRID MODEL)
TEMPORAL & KINETIC DEFINITION
Solar Radiation
Temperature
Flow
Nutrients
LAKE 1 MODEL 3 VERTICAL LAYERS
Phytoplankton & Zooplankton Dynamics
LAKE 2 MODEL 7 VERTICAL LAYERS
Temperature Verification Phytoplankton, Chemistry & Sediment Interactions

FIGURE I
EUTROPHICATION MODELING STRATEGY

III. Project Status The three years planned for this project are scheduled as follows:

Year #1: During the first year, attention is to be directed toward data compilation and first preliminary analyses to provide the necessary information for the overall modeling structure.

Year #2: The second year will begin incorporation of major sub-systems into the modeling framework. Verification and sensitivity analyses using previous data and IFYGL data will be completed on preliminary models and will be applied using the more detailed spatial models (See Fig. 1).

Year #3: Final verification analyses of the larger detailed spatial model will be completed during this year. Simulations will be prepared of selected future environmental controls.

The project is essentially on target and the goals of Year #1 have been completed as discussed more fully below in Sect. IV, Summary of Results. No areas of the project are behind schedule at the present time.

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IV. Summary of Results

1. Data Compilation

A major effort during the first year was devoted to the gathering and analyses of data collected on Lake Ontario prior to IFYGL.

The bulk of data used in the first year effort was obtained primarily from three sources.

1. Limnological Data Reports, Lake Ontario, 1966-1969, Canada Centre for Inland Waters (CCIW).
2. STORET, Environmental Protection Agency.
3. Report to the International Joint Commission on the Pollution of Lake Ontario and the International Section of the St. Lawrence River; International Lake Erie Water Pollution Board and the International Lake Ontario - St. Lawrence River Water Pollution Board, 1969.

These sources were supplemented with other data available in the literature.

This data base after being surveyed to determine completeness was used for model inputs and as data for verification analyses.

The Limnological Data Reports (LDR) of CCIW comprise the largest single source of Lake Ontario survey data available. CCIW's cruises not only had adequately dense spatial grids but also comprised good temporal coverage for the years surveyed. It was therefore decided to use the data contained in the LDR as a verification data base. The CCIW data were also manipulated to aid in the formulation of a modeling framework.

A display procedure showing the spatial variations in Lake Ontario, using contours, for a given cruise and sampling depth was tested. A preliminary set of contours for a given year and certain variables was generated for use in the first year development of the model. Contours will be used not only to give insight into where model grid detail will be important but also as a means to facilitate data comprehension.

Due to the magitude of data in the LDR, a reduction mechanism had to be found which would make the data easily compatible with model output to facilitate comparison. Since a segmentation scheme was used which represented the lake as 3 or 7 vertically layered completely mixed volemes, temporal plots of variables were made.

The program which generated the plots has the option to retrieve selected stations of the cruises by testing the depth of the station and thereby limiting a retreival to near shore or main lake stations. A further option which can be selected is that only samples collected between a specified depth interval will be retreived. Latitude - longitude constraints are also possible.

After reviewing the years surveyed for completeness of variables measured and time coverage of cruises, 1967, 1969 and some data for 1970 were chosen as the years for model comparison. Plots were generated for key variables using depth intervals corresponding to the vertical segmentation of the model. Since the model LAKE 1 considers the lake as 3 vertical layers, the main lake option was selected. The program plots all points against time and calculates the mean and standard deviation for each time (i.e. cruise).

The base data are then compared with model generated data. This comparison is facilitated by plotting model output and overplotting the mean and mean plus standard deviation for the base year, for the key variables versus time.

Storet, the Environmental Protection Agency's water quality storage and retreival system is the prime residence of all U.S. collected water quality data. A water quality inventory using a polygon retreival, was run for Lake Ontario. This gave a summary of all historical data collected on Lake Ontario. A retreival was also run which listed all the data and punch card output was also generated. Storet's main utility will be for IFYGL data and will also be used as a data base for tributary nutrient concentration data and flow records, and also as supplement to the LDR of CCIW.

The report to the International Joint Commission (IJC) on Lake Ontario is a comprehensive pollution study, giving an excellent overview of the Lake. The values reported were used in the forty segment chloride model for chloride discharge loading and in the development of a transport structure. The transport was structured by translating the velocity vectors given for mean circulation patterns into intersegment flows.

The vertically layered phytoplankton model used the IJC's discharge loadings as nutrient forcing functions. This loading information, which is divided by source of discharge is categorized under three headings; municipal, industrial and tributory. These loadings are used as boundary conditions and forcing functions for the nutrient systems in the spatially defined phytoplankton models.

2. Preliminary Kinetic Model - Lake 1

As outlined in Fig. 1, the modeling strategy developed for structuring the overall framework calls for preparation of a preliminary model with emphasis on the interactive kinetics of major components of the eutrophication phenomena. The development of such a model was dictated by the recognized need to make a number of computer runs to elucidate system sensitivity and to compare model output to observed data. The kinetic model of necessity will have a finite life as new systems are added to the modeling structure and new insights are gained.

The model has been designated as the Lake 1 model. The basic physical features included in the model are shown in Fig. 2. As shown, the model is well-mixed horizontally and vertically is divided into the epilimnion, hypolimnion and benthos. Mixing in the vertical direction is allowed during isothermal conditions and is restricted during the summer to simulate vertical stratification.

The sub-systems included in Lake 1 have evolved over the past year from a basic seven system (variable) model to a present configuration of ten systems shown in Fig. 3. The Lake 1 model is divided into two broad areas, a biological sub-model and a chemical-biochemical sub-model. The interactions shown in Fig. 3 are both linear and non-linear. Detailed mathematical expressions are written for each system and interaction. The ten systems and the three spatial segments shown in Fig 2 result in a total of 30 simultaneous non-linear differential equations to be solved.

If one defines a compartment as one dependent variable at a particular spatial location, LAKE 1 is considered as a thirty compartment model. A finite difference scheme is used

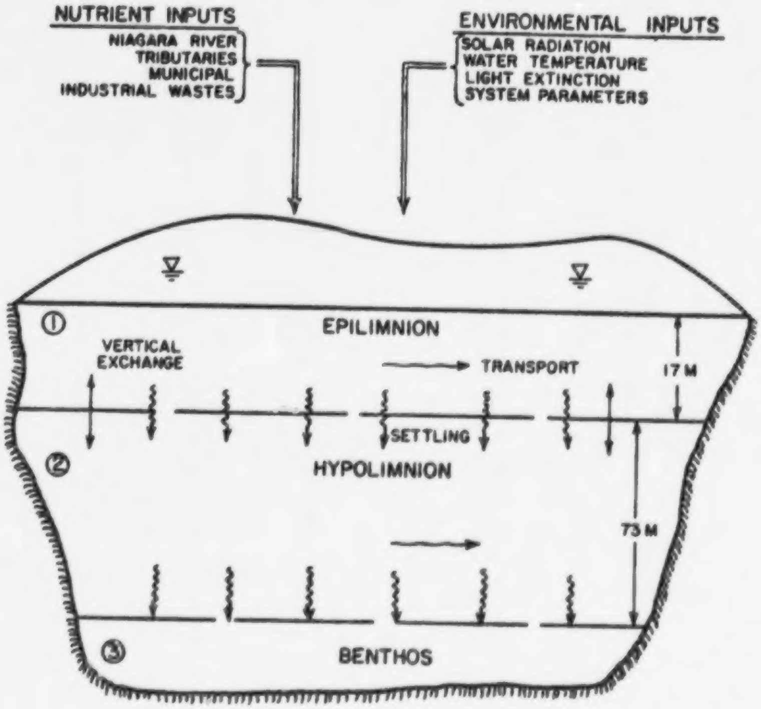

NUTRIENT INPUTS
NIAGARA RIVER
TRIBUTARIES
MUNICIPAL
INDUSTRIAL WASTES
ENVIRONMENTAL INPUTS
SOLAR RADIATION
WATER TEMPERATURE
LIGHT EXTINCTION
SYSTEM PARAMETERS
①
EPILIMNION
VERTICAL EXCHANGE
TRANSPORT
17 M
SETTLING
②
HYPOLIMNION
73 M
③
BENTHOS

FIGURE 2
MAJOR PHYSICAL FEATURES INCLUDED IN LAKE 1 MODEL

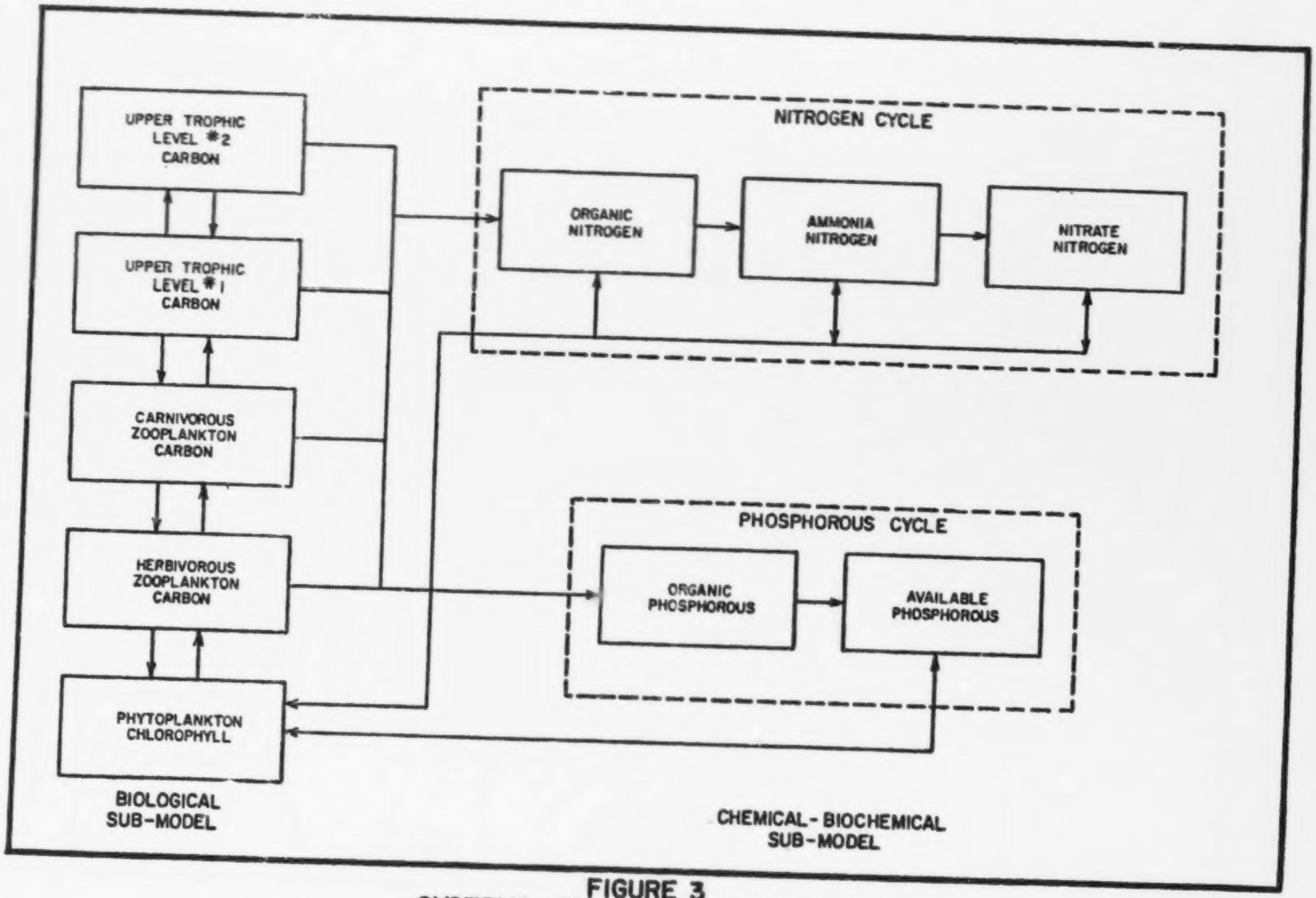

UPPER TROPHIC LEVEL #2 CARBON
UPPER TROPHIC LEVEL #1 CARBON
CARNIVOROUS ZOOPLANKTON CARBON
HERBIVOROUS ZOOPLANKTON CARBON
PHYTOPLANKTON CHLOROPHYLL
BIOLOGICAL SUB-MODEL
NITROGEN CYCLE
ORGANIC NITROGEN
AMMONIA NITROGEN
NITRATE NITROGEN
PHOSPHOROUS CYCLE
ORGANIC PHOSPHOROUS
AVAILABLE PHOSPHOROUS
CHEMICAL-BIOCHEMICAL SUB-MODEL

FIGURE 3
SYSTEMS DIAGRAM-LAKE I MODEL

to solve the equations using explicit time-space differencing. For the LAKE 1 model, a time step of 0.5 days was used. For a one year simulation, the central processing unit (CPU) time required for execution is about 7 seconds. Total CPU time required however is 30 seconds with additional overhead converted to equivalent CPU time being 115 seconds. The CPU time excluding overhead is equal to about 1.4 milliseconds per compartment step. A number of runs have been made using the Lake 1 model structure. The purposes of these runs are to 1) test program elements 2) study the behavior of the system and its sensitivity to various system parameters and inputs and 3) prepare a preliminary verification of the Lake 1 model using data collected prior to IFYGL. These early runs therefore represent a type of "tuning" of the model using past data preparatory to a more independent verification of the IFYGL data. The Lake 1 model has been used to examine several areas including:

1) Variable levels of spring and fall vertical mixing
2) Settling velocities for phytoplankton.
3) Zooplankton grazing rate
4) Zooplankton and higher-order predation using up to four trophic levels

Some of the output from these areas is discussed below:

(a) Variable Vertical Mixing

Vertical mixing and dispersion are important phenomena in the dynamics of phytoplankton population in lakes. Fig. 4 shows the effect of vertical dispersion on chlorophyll a. The runs include a sinking velocity of 0.05m/day. A bimodal

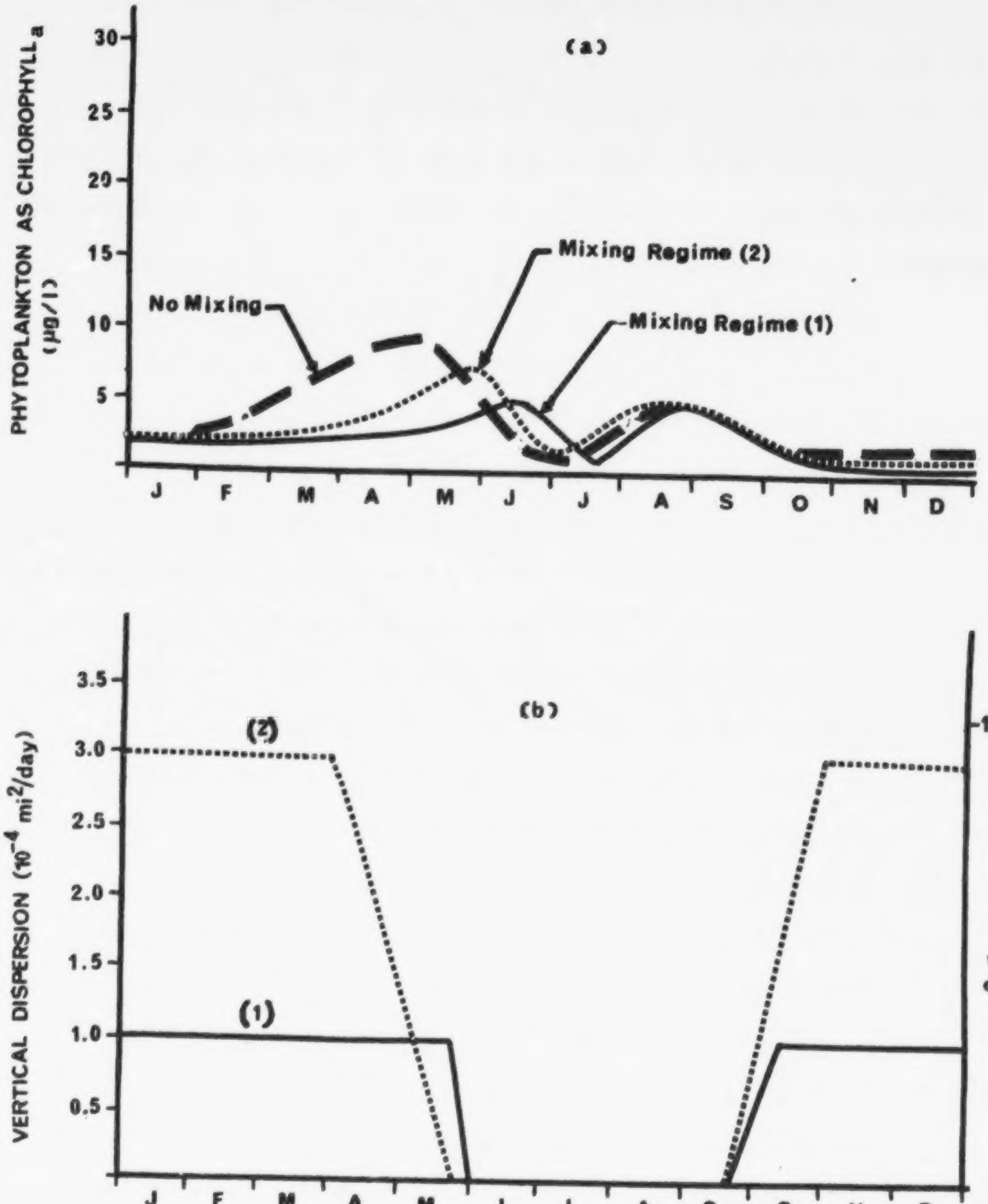


FIGURE 4 EFFECT OF VERTICAL DISPERSION

(a) PHYTOPLANKTON AS CHLOROPHYLL $_a$

(b) VERTICAL DISPERSION REGIMES

distribution of phytoplankton occurs in all cases due to the interaction of the two higher zooplankton levels used in these runs. As populations build up in the spring, the herbivorous zooplankton increase. This together with nutrient **depletion** decreases the phytoplankton population and at about the same time, the carnivorous zooplankton prey on the next lowest trophic level. The phytoplankton can then increase again in the late summer.

As shown in Fig 4, the main effect of vertical mixing is in the spring where populations increase more rapidly when no mixing is allowed and reach a peak earlier. With mixing, the first peak is delayed and reduced in magnitude. The results in the summer and early fall are generally comparable under the different dispersion regimes although the timing of maximum and minimum is changed.

(b) Variable Phytoplankton Settling Velocity

A number of analyses using the Lake 1 model have been made to examine the behavior of the phytoplankton population under different settling velocities. The literature has been reviewed for typical ranges of phytoplankton settling velocity and it subsequently became clear that many of the published values for phytoplankton sinking in quiescentwater are much too high to support growth. This is due to the importance of other factors such as vertical dispersion and the interaction between the sinking of phytoplankton and their physiological state. Phenomema such as the generation of gelatinous sheaths by phytoplankton have been shown to be of importance in settling. Published values of the sinking velocity of phytoplankton range from 0.07 - 18 meters/day. In some instances, of course the settling velocity is zero or negative as in the case of blue green algae. Some net deposition of phytoplankton must occur in lakes like Lake Ontario on the basis of examinations of the sediments. Accordingly, the model should include this phenomenom and during this stage of the work, the settling velocity has been treated as a parameter at two levels - 0.5, 0.05 meters/day in addition to the zero settling velocity case.

Fig. 5 summarizes the results from several analyses using differing sinking velocities. For these runs, zooplankton grazing was set at 0.06 l/mg carbon-day-°C and no vertical mixing was used. At a velocity of 0.5m/day phytoplankton populations never exceed about 3μg chlor/l and total zooplankton carbon Fig. 5b) never exceeds about 0.08 mg Carbon/l. Both values are considerably less than observed as shown later. The reason for the low levels is that under a settling velocity of 0.5m/day (which for the 17 meter depth of the epilimnion represents a "decay" coefficient of .03/day), the phytoplankton are not retained in the upper layer long enough to undergo net growth. As a consequence, zooplankton levels are also low and the nutrient concentrations remain high and are not reflective of observed nutrient depletion. On the basis of runs like those shown in Fig. 5, it was concluded that if a reasonable grazing coefficient is used, net settling velocities for that model must be substantially less than 0.5m/day. Using a velocity of 0.05m/day,

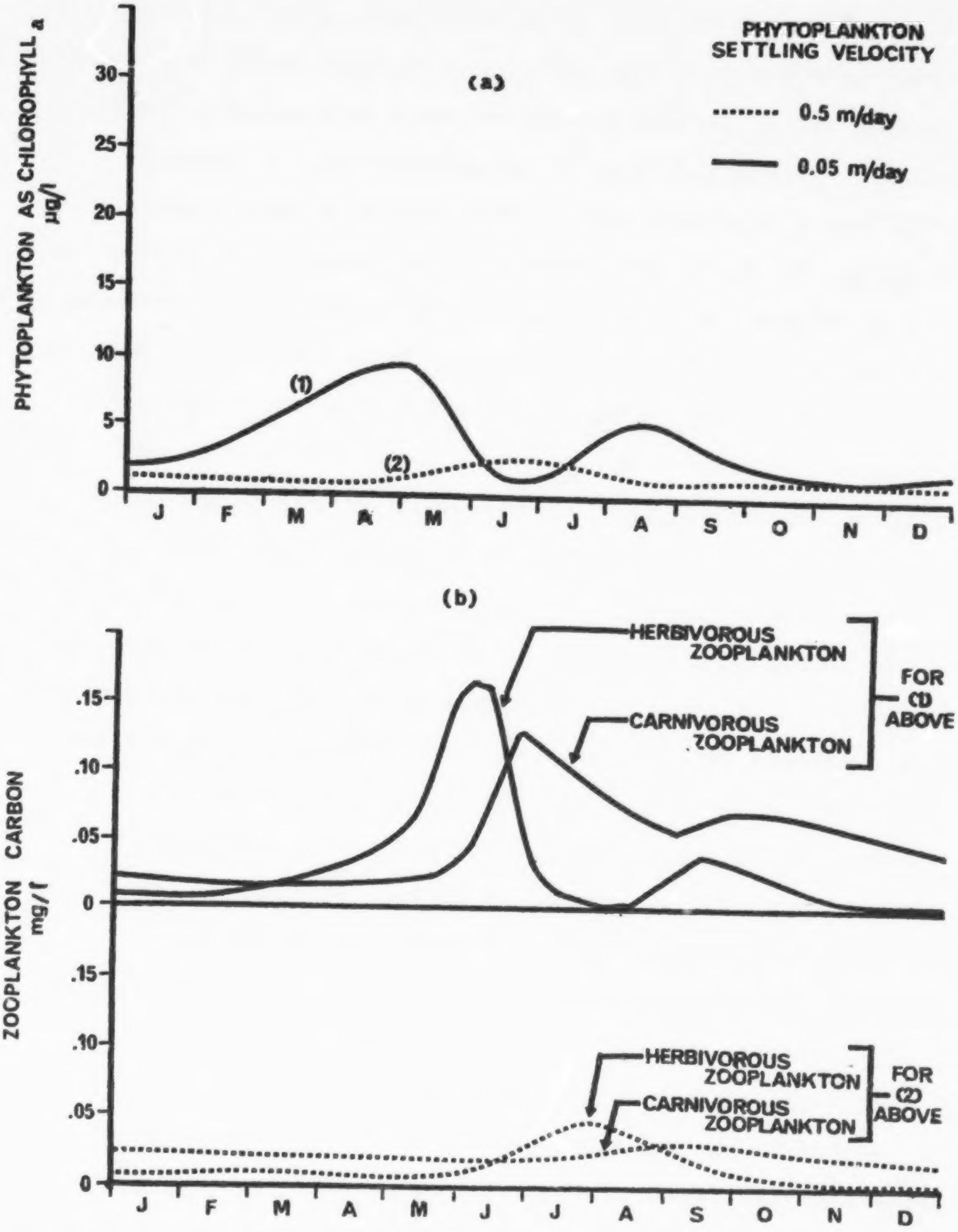
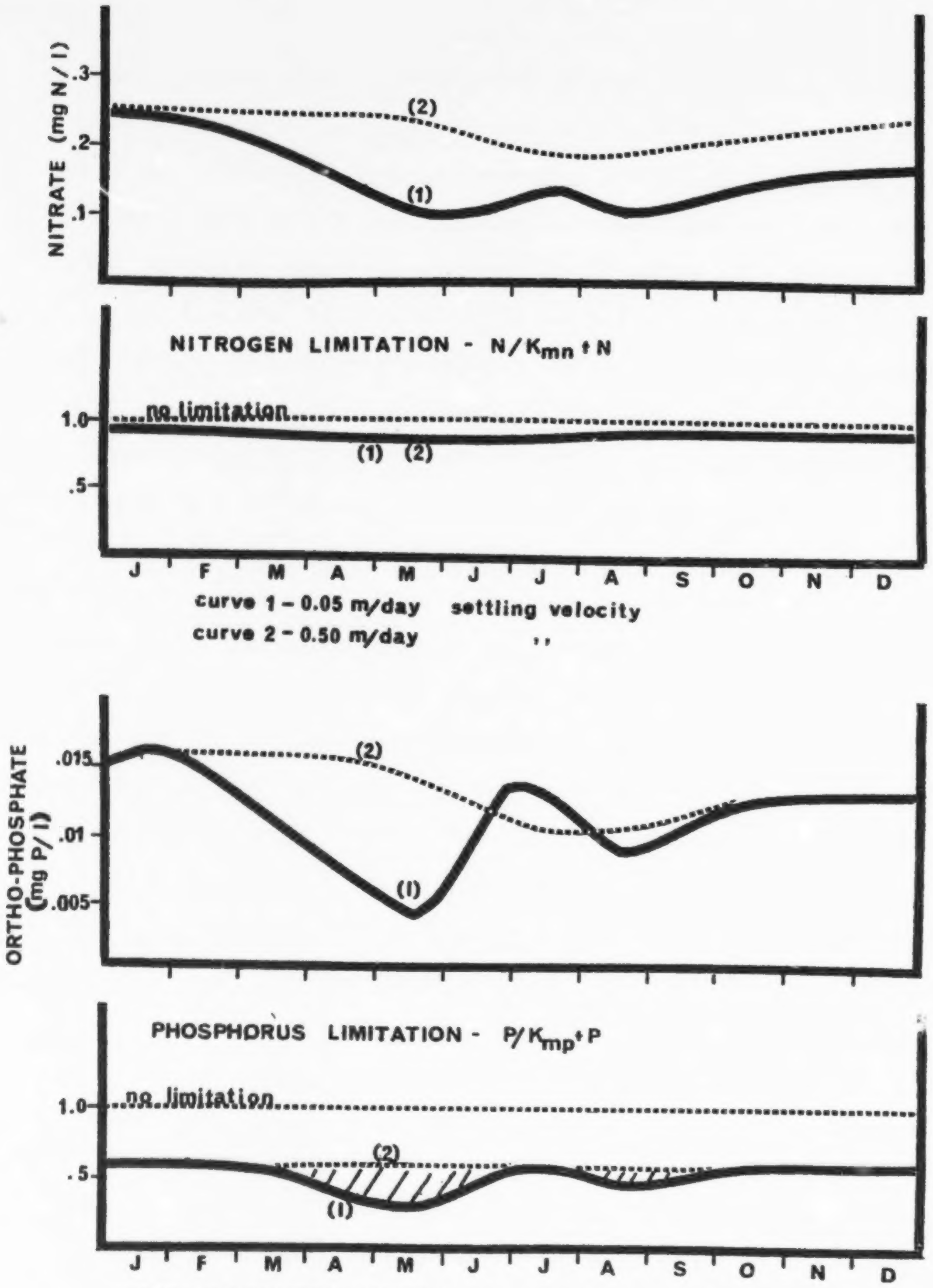


FIGURE 5 EFFFCT OF PHYTOPLANKTON SETTLING VELOCITY
a) PHYTOPLANKTON
b) ZOOPLANKTON

the behavior of the phytoplankton biomass is quite different as shown in Fig. 5 (a). Now, the lower trophic levels have a chance to grow and a reasonable predator -prey relationship begins to develop. Curve 1 of Fig. 5 (a) exhibits the two peaks in chlorophyll discussed above. Zooplankton biomass carbon as shown in Fig 5b for the lower settling velocity is greater than 0.1 mg carbon/l and approaches 0.2 mg carbon/l. These values are closer to observed zooplankton carbon levels. The sinking velocity of phytoplankton also has an important effect on the nutrient uptake as shown in Fig. 6 which is a plot of the nitrate and orthophosphate concentrations calculated under the two velocity conditions. In addition, Fig. 6 shows the nitrogen and phosphorous limitation terms, i.e. the ratio of total inorganic nitrogen to total inorganic nitrogen plus the Michaelis or half-saturation constant for nitrogen and similarly for available phosphorous. The half-saturation constant for nitrogen for these runs was set at K_{mn} = 25μg/l and for phosphorous at K_{mp} = 10μg/l. It can be seen that nutrient uptake and growth limitation is minimal for the case of sinking velocity = 0.5m/day. This is a result of the minimal phytoplankton growth as shown in Fig. 5. At the lower sinking rate, however, nitrate uptake is increased and the computed values approach but do not reach those that are observed. As indicated in the upper curves of Fig. 6, nitrogen does not significantly limit growth.

The lower curves representing the phosphorous dynamics however do exhibit a limiting effect. If attention is directed



EFFECT OF PHYTOPLANKTON SETTLING VELOCITY ON NUTRIENTS AND NUTRIENT LIMITATION

FIGURE 6

to the phosphorous limitation term, it is seen that for both settling velocity cases, levels of phosphorous are such that a limitation of .50 - 0.60 prevails during the early and later parts of the year. However, substantial differences occur in the spring and late summer. At day 135, a minimum value of 0.28 is calculated indicating that phosphorous is acting as a significant limiting factor in the phytoplankton growth. This helps explain the decrease in phytoplankton biomass beginning at day 120, (see Fig 5). Two effects are occuring: a)herbivorous zooplankton are growing rapidly and b) phosphorous levels are being depleted to below the half-saturation constant thereby acting to reduce the growth rate. It is interesting to note then that a biomodal distribution in phytoplankton can be obtained without a species differentiation. The latter is often offered as the explanation for the observed two peaks in the phytoplankton. In order to accomplish this however, at least two trophic levels must be included above the phytoplankton. This permits a higher order predation, e.g. carnivorous zooplankton which reduces the lower zooplankton level. The reduction (as shown at day 210 of Fig 5b, for the lower settling velocity) permits phytoplankton to grow again in late summer.

The sequence of events just described, and the display of the calculations in Figs 4 - 6 is not put forth as any definitive explanation of the "true" course of events. Much work remains to be done on the model; the results are simply presented to show the behavior of the system and to offer possible effects that may be important. The veracity of even the preliminary model depends to some degree on the comparison of model output with observed data.

(c) Comparison of Lake 1 model with Observed Data

Figs 7 and 8 show observed data for the main lake stations for phytoplankton chlorophyll a and zooplankton carbon. As seen, chlorophyll a levels are generally less than 5μg/l during the winter and early spring and the increase to 5 - 10μg/l during the late spring. There is some indication of a summer minimum especially in 1967 and 1969. During the late summer and early fall, chlorophyll levels again increase to slightly greater than 5μg/l.

The 1967 data are an exception to the general level of chlorophyll a of 5μg/l. As shown in Fig. 7, a spring average concentration of about 20μg/l is reported for the main lake stations. This order of concentration for the entire lake has not since been reported and is considered, for purposes of preliminary model verification, to be an anomalous situation.

The zooplankton carbon ranges shown in Fig. 7 were obtained from published sources and represent only approximately the lake wide situation. The important point from a modeling point of view is that zooplankton carbon of greater than 0.1mg/l should be calculated by the preliminary model. (See for example, Fig. 5b).

Figs 9 and 10 show comparison of model output with observed chlorophyll a range, total Kjeldahl nitrogen, nitrate nitrogen and reactive phosphate.

The model structure used in the output shown in Figs 9 and 10 includes the following:

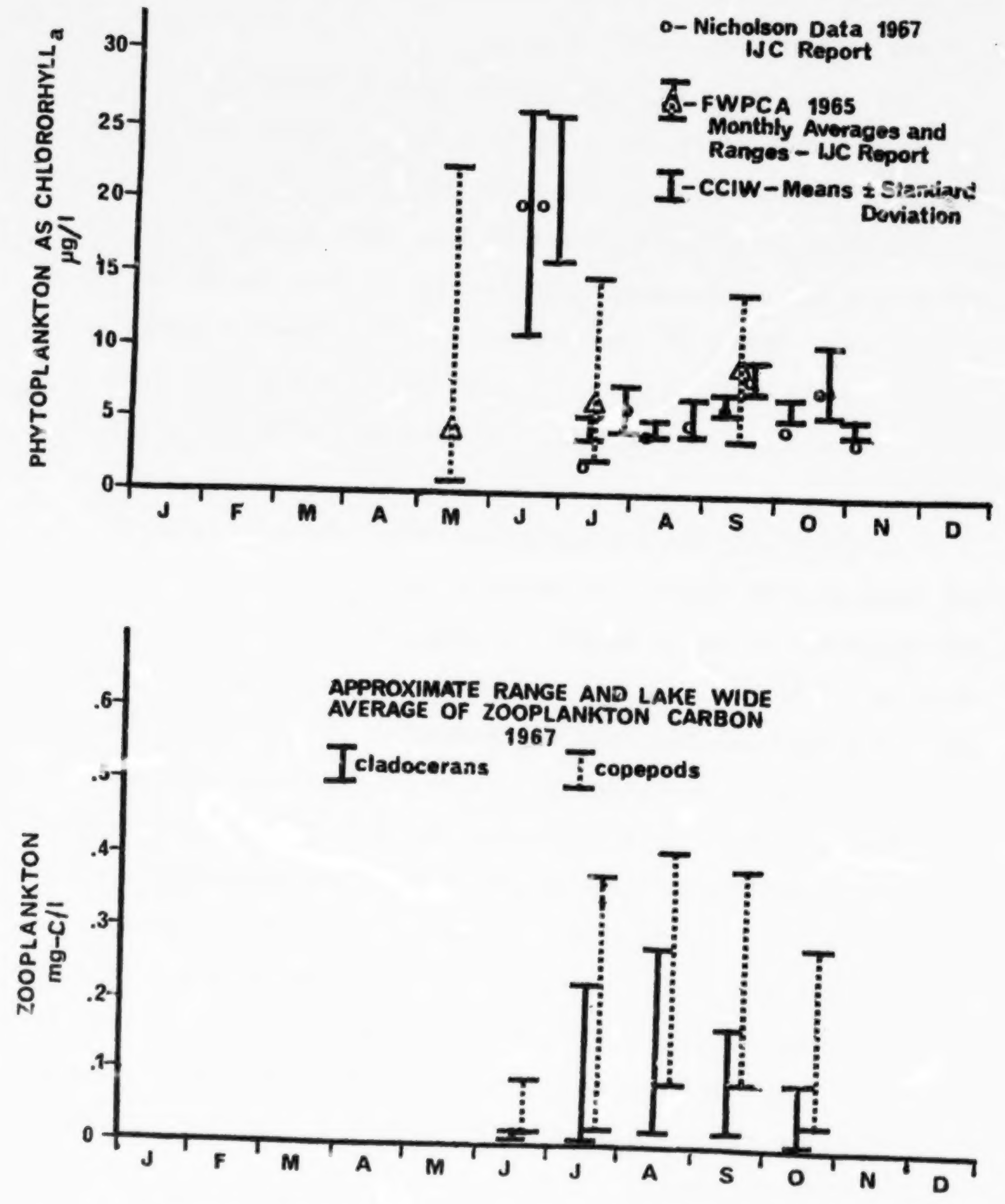


FIGURE 7 PHYTOPLANKTON CHLOROPHYLL$_a$, 1965, 1967 & ZOOPLANKTON CARBON - LAKE WIDE AVERAGES

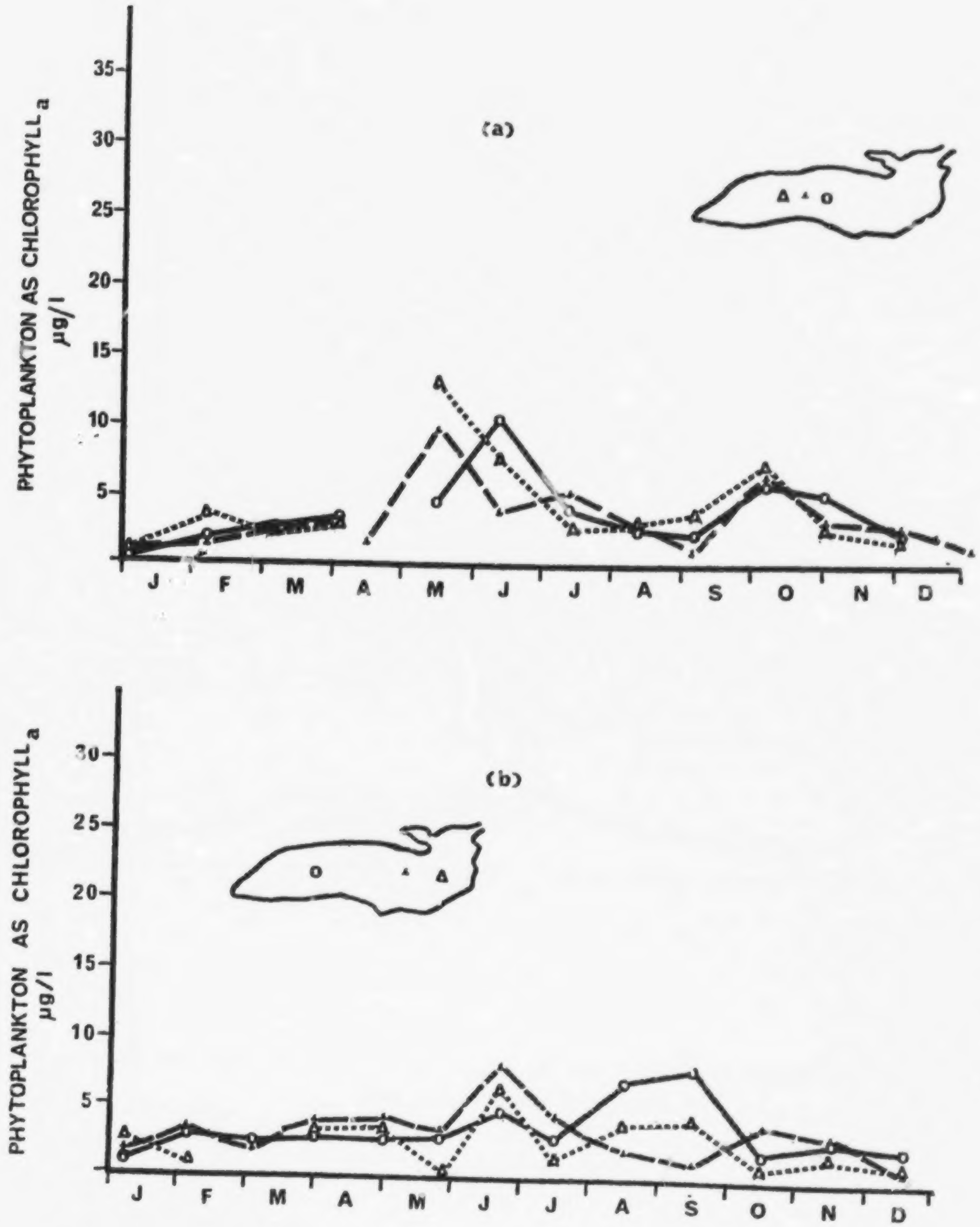


FIGURE 8 PHYTOPLANKTON CHLOROPHYLL $_a$ FOR SOME MAIN LAKE STATIONS
a) 1969
b) 1970

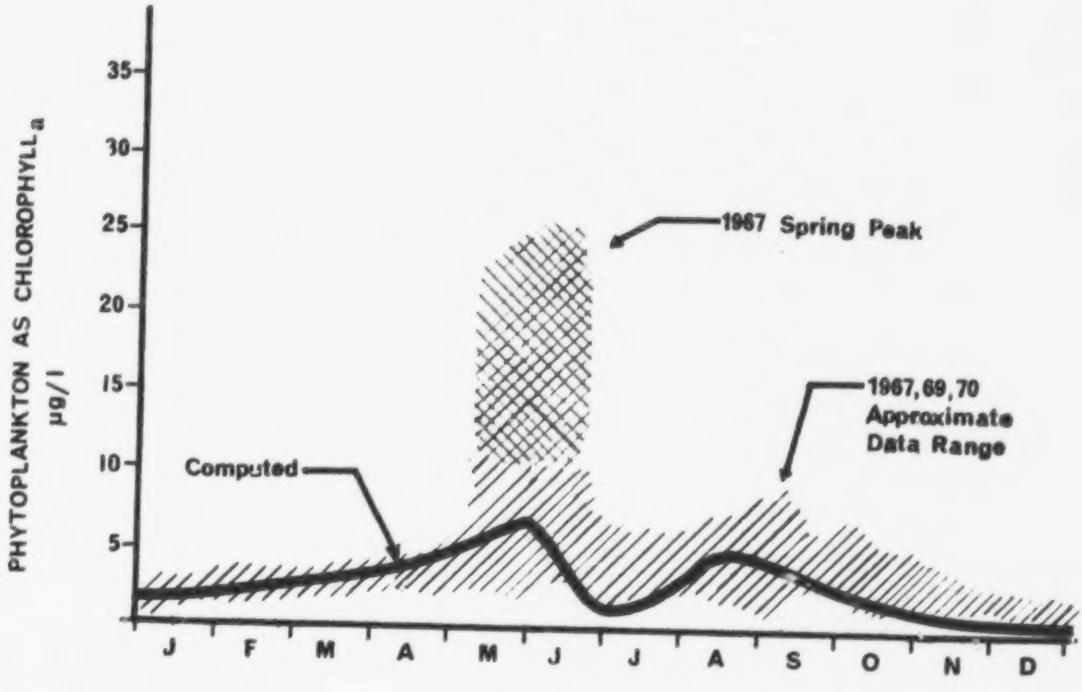
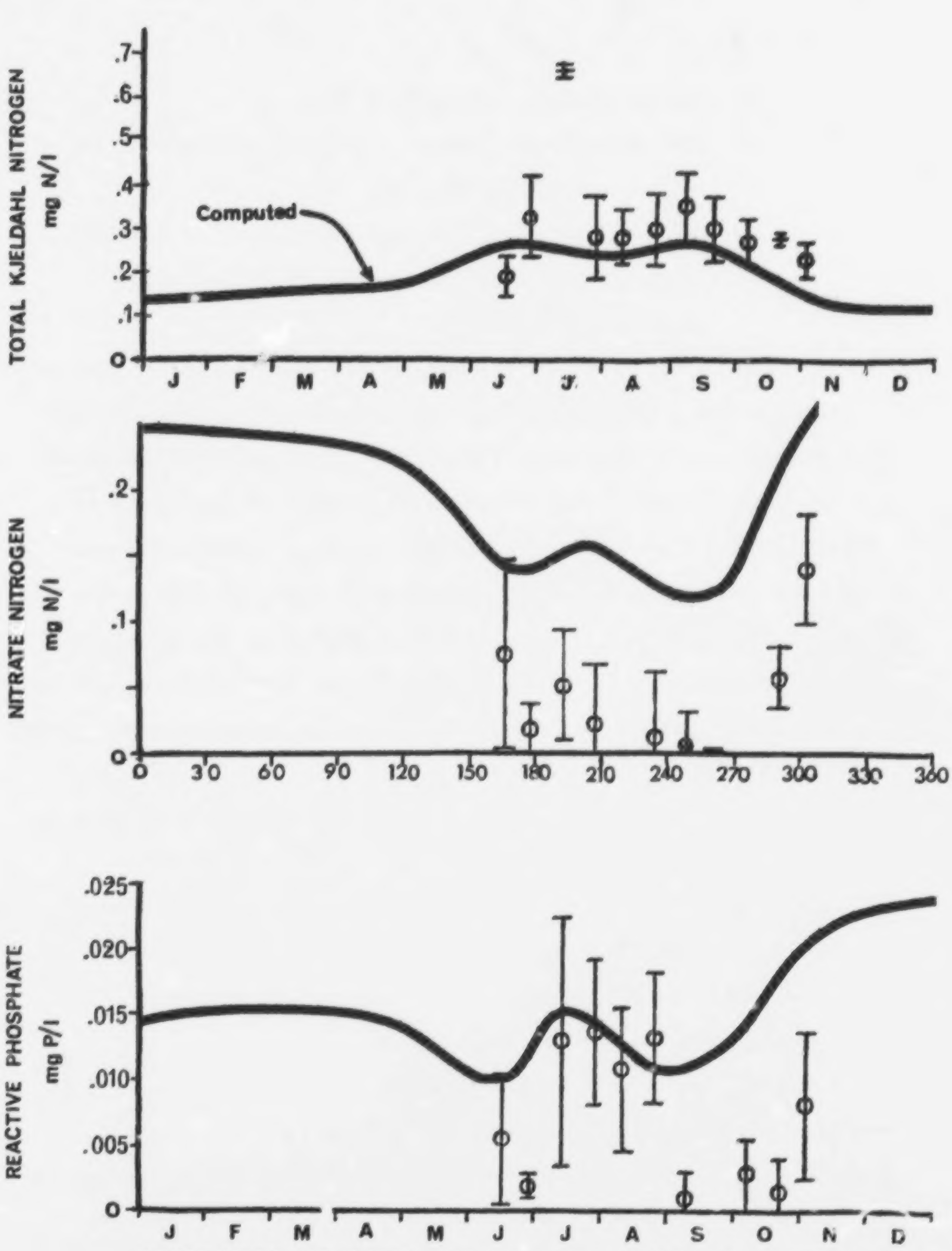


FIGURE 9 COMPARISON OF MODEL OUTPUT WITH RANGE OF OBSERVED CHLOROPHYLL$_a$ DATA



COMPARISON OF MODEL OUTPUT WITH OBSERVED NUTRIENT DATA
FOR 1967 - MAIN LAKE

FIGURE 10

1) Mixing regime (2) of Fig 4(b)

2) Two zooplankton levels - grazing coeffecient of each = .06 l/mg Carb - day - ^{o}C

3) Settling velocity for phytoplankton = 0.05m/day

4) Half-saturation constant for total inorganic nitrogen = 25μg Nit./l

5) Half-saturation constant for phosphorous = 10μg p/l

In general, the preliminary verification is quite good and reproduces some of the major features of phytoplankton dynamics and nutrient uptake. In all cases, the order of magnitude is reproduced and the dynamics are approximately correct although there are several areas that warrant more detailed work. For example, the nitrate nitrogen is not depleted in the model as much as is observed. This is attributed to the coarseness of the preliminary model with its single volume representation of the epilimnion. The observed nitrate data shown in Fig. 10 are for the surface of the lake while the model output represents an average over the top 17 meters.

The 1967 high values of chlorophyll are not duplicated by the model. Indeed, the model indicates that a very substantial nutrient input would be required to grow up to 20μg/l chlorophyll over the entire lake.

Overall, the results are encouraging although it should be recalled that the model does not yet exhibit any horizontal detail. Further, it should be stressed again, that the model as presently constituted is not considered to be a definitive explanation of the observed data. The model does indicate however, that some major features of phytoplankton and nutrient behavior can be reproduced and the model therefore provides a basis for extension to the more detailed spatial computation.

GRANT NUMBER 800646

A NEAR SHORE SURVEY OF EASTERN LAKE ONTARIO

PART I

Under Grant Agreement R-800646

from

United States Environmental Protection Agency

by

Richard B. Moore
Lake Ontario Environmental Laboratory
State University of New York
College of Arts and Science
at Oswego

November 1973

Near Shore Study of Eastern Lake Ontario (IFYGL)

INTRODUCTION

The Great Lakes System is truly one of nature's wonders which contain an estimated 20 percent of the world's fresh water supply. Thirty-five million people live within the drainage basin of the Great Lakes--St. Lawrence River System with this number rising to forty-four million by 1980. Intensive use for multiple purposes of this water system has resulted in controversy and increasingly difficult management problems.

Information is needed to serve as the basis of rational management decisions to solve the problems of eutrophication, multiple use and crossing of international boundaries. An effort to gather this information resulted from the International Year for the Great Lakes (IFYGL), a joint study of Lake Ontario by the United States and Dominion of Canada.

The primary objective of the IFYGL was to investigate a number of problems associated with hydrology, meteorology, physical limnology, biology, chemistry and geology of Lake Ontario and its drainage basin.

The following is an initial report summarizing chemical and biological studies of Eastern Lake Ontario.

REASONS FOR PROJECT

Most substances enter Lake Ontario from rivers and surface runoff. The major effects of these substances is first seen in the near shore waters. Such physical parameters as currents and the thermal bar tend to trap and retain these materials within these near shore areas. Effectively, then, the near shore region remains separate from the rest of the lake and has chemical and biological parameters which are distinctly different from the remainder of the lake.

The southern shore of Lake Ontario includes the outflows from two large polluted rivers and from a number of smaller streams. There are several estuaries, some of which are highly eutrophic. Two conventional and two thermonuclear power plants release heated effluents into the study area Many more are planned. All of these inputs influence the biology and chemistry of the lake and, in turn, the uses of the lake.

Many cities and towns along the southern shore obtain their water from the lake. Even inland cities, such as Syracuse, New York, use the lake as a source of water. This study has provided data for use in evaluating the areas from which present supplies are obtained and for use in locating possible sites for future supplies.

Most of the recreational activities on the lake occur in the near shore region. Here the results of increased nutrient input and pollution in general are most easily seen. Beaches become clogged with Cladophora. Large mats of this alga tend to float throughout the near shore waters usually at a time when this region is most intensely used for recreation. Most sports also place within the near shore zone. Biological, chemical and physical parameters within this area directly affect fishing patterns and the amount and species of fish present.

A hydrographic survey of the type reported here provides baseline data from which future changes in the lake can be measured. The survey also points up areas which require more detailed study. New areas of enrichment, whether chemical or thermal change, can be evaluated in terms of the reference conditions found.

The results of this study also provides input for the formulation of lake models. Since most of the physical, chemical and biological activity occurs first in the near shore waters, the information provided by this study is essential to any proposed modeling of lake processes.

PROGRAM OBJECTIVES

1. To obtain information on present status of Lake Ontario throughout the near shore region. This can be used as a baseline for future informational requirements and to provide input for the information of predictive models of lake processes.
2. To determine the flow of nutrients into, within and out of the near shore including movements within the biological system.
3. To ascertain the space-time distribution and identification of zooplankton, phytoplankton and benthos populations within the eastern near shore area.
4. To examine the extent of Cladophora growth throughout the eastern near shore region and to determine its growth patterns and to attempt to find means by which this problem alga can be controlled.

5. To determine the distribution of polychlorinated biophenyls (PCB's) and chlorinated pesticides in water, sediment and organisms.

AREA OF STUDY

The region of study was the southeastern portion of the near shore zone of Lake Ontario comprised of 140 km of shorline extending from Rochester, New York, to Stony Point on the east (Figure 1). A total of fifteen sampling transects consisting of three stations each were established at ten meter intervals along the coast (Figure 2). The stations along each transect were normal to the coast line and located at 0.5, 4.0 and 8.0 Km from shore. These stations were located during each cruise with the aid of a Decca Navigational System. Decca coordinates were determined from Decca charts specially prepared for IFYGL. Latitude and longitude were also determined for each station from these charts. Table 1, Appendix 1, lists station number, latitude and longitude, Decca coordinates and depth of water in meters.

Intensive sampling of the Oswego River and Black River mouths was accomplished to determine the chemical and biological impact of these rivers on contigrous parts of the lake. There were twenty sampling stations on the Oswego River (Figure 4) and fifteen stations on the Black River.

A total of ten cruises were completed in the period of April through December, 1972. The first cruise was not implemented until June 1972 because of late funding and subsequent delays in delivery of equipment. Each cruise consisted of 45 stations on the eastern end of Lake Ontario as prescribed in the operation plan.

Samples collected on each cruise consisted of water, chlorophyll, zooplankton, and phytoplankton. Specific samples collected seasonally were benthos, pesticides, Cladophora, and sediments for various chemical analyses. In all, over 6,000 samples of all types were collected and preserved for analysis. Listed below is a breakdown of sample numbers by type.

Samples Collected on Eastern Near Shore Program

Water Samples	
Heavy Metals Analysis	666
Dissolved Nutrients	720
Total Nutrients	912
Chloronhyll Analyses	711
Phytoplankton Quantitation (Lugols Treated)	551
Zooplankton Quantitation	1094
Benthos	272
Sediment Chemistry	
Pesticides	
Heavy Metals	59
Nutrients	402
Phytoplankton Biomass	
Pesticide Chemistry and PCB Quantitation (water, sediment, plankton, fish)	500
Cladophora Biomass	120
TOTAL	6007

METHODS AND MATERIALS

Methods of Sample Collection and Analyses for the Eastern Near Shore Survey of Lake Ontario (IFYGL)

The eastern near shore survey of Lake Ontario consisted of fifteen transects with three stations per transect for a total of forty-five stations. Each station required the collection, initial analysis and preservation of water samples, and the collection and preservation of phytoplankton and zooplankton. Light and temperature readings were also required at each station.

Periodically throughout the field year, benthic and sediment samples for nutrient analysis were taken as well as water and sediment samples for pesticide studies.

WATER SAMPLES

The water samples were collected at every station from three depths; surface, mid-depth, and bottom. The samples were collected using 8.1 liter Van Dorn water samplers suspended simultaneously at the prescribed depths on a vinyl coated cable. Since the water was analyzed for heavy metals, PVC sample bottles were used. When the water samples were brought aboard, dissolved oxygen content was immediately determined. The Winkler Method was used as per Standard Methods for Water and Wastewater Treatment (13th Edition). The results were reported in milligrams per liter.

Total alkalinity was also determined shipboard. One thousand mls of sample water was titrated with .020 N H_2SO_4 using 5 drops of methyl orange as an indicator. The samples were titrated to a color of salmon pink against a standard made up of 100 mls of deionized water and 5 drops of methyl orange. The burett reading was multiplied by 10 to give the total alkalinity reported as milligrams per liter as calcium carbonate.

The pH of the sample water was determined using a Photovolt model 126A pH meter.

The light transmission of the waters at each station was recorded using a tsuruml Seike Submarine photometer. The instrument is equipped with both deck and submarine photocells so a deck illumination reading and submarine illumination readings were taken. Submarine readings were taken at 0.2 meters, 1 meter and at one meter intervals to the depth where there was zero light penetration. Light intensity in lux was determined from standard curves.

The temperature of the water was taken at the surface and at one meter intervals down to the bottom. A Whitney model TC-5C thermister was used. The temperatures were reported in degrees centigrade.

Besides the preliminary analysis of the water, samples were also sent to EPA Rochester Field Station for further analyses. Liter plastic sample bottles were throughly washed then rinsed twice with a solution of one part concentrated nitric acid and one part water. The bottles were then rinsed twoce with deionized water. The bottles were filled with sample unfiltered water and treated with 2.5 ml concentrated nitric acid and 2.5 mls concentrated redistilled hydro chloric acid. Five hundred mls of the sample water was placed untreated in a plastic bottle and frozen immediately. Another five hundred ml sample was first filtered through a millipore apparatus using a filter with a 45 micron pore size. The water was then transferred to plastic sample bottles and frozen at -20°C.

Another 2 liters of the sample water was drawn and used for chlorophyll analysis. The water was drawn through a 47 mm glass fibre millipore filter and discarded. The filter was wrapped in aluminum foil and frozen. Chlorophyll samples were collected at the same depths before mentioned.

ZOOPLANKTON

As part of the procedure at each station, zooplankton samples were taken. The samples were secured using a 1.5 mesh. Plankton tows were drawn from 5 meter intervals up to 30 meters in depth, then every 10 meters down to 50 meters and from the bottom. If the bottom was over 100 meters in depth, then an additional tow was made from 70 meters. The plankton in the net was washed into the cup by spraying the net with lake water from a hose from the outside of the net as to avoid contamination of the samples. The samples were then transferred to 250 ml plastic bottles. The zooplankters were narcotized with carbonated water for ten minutes and preserved with formalin buffered with sodium acetate to pH 8.

PHYTOPLANKTON

Quantitative samples of phytoplankton were taken at every 5 meters and bottom at near shore stations and every 15 meters and bottom at mid and outer stations. 2 liters of the water was concentrated by pouring it through a NO. 25 mesh plankton cup. The contents of the cup was then transferred to a 250 ml sample bottle. The plankton cup was rinsed three times with deionized water and the rinsing also poured into the sample bottle to assure the quantitative transfer of the organisms. The samples were preserved with a Lugols solution.

PHYTOPLANKTON BIOMASS

Biomass samples were taken at each station. These samples consisted of two verticle tows, using a 1.5 meter No. 25 mesh plankton net, from the bottom. The contents of each tow was transferred to a separate sample bottle and frozen immediately.

BENTHIC AND SEDIMENT SAMPLES

Benthic and sediment samples were collected using a .05 sq meter ponar dredge. Three replicate samples were taken at each station, each sample being washed through a #20 mesh screen. The samples were preserved separately with a 10% formalin solution. For the sediment samples, mud was packed in mason jars and cooled to 5°C.

CLADOPHORA BIOMASS

Cladophora samples were taken at 3 times during the field year. The samples were secured by divers using scuba. A Plexiglass box was placed and the substrate covering in area of 1000 square centimeters. All of the *Cladophora* in that area was removed, packed in jars and chilled for transportation to the on shore lab where they were frozen at -20°C until analysis.

Temperature measurements, transparency, pH, alkalintiy and dissolved oxygen values were also taken at each *Cladophora* station. The temperature was recorded for every meter in depth using the Whitney Thermister. The transparency of the water was arrived at by using a Sechi Disk. The pH, alkalinity and dissolved oxygen were all taken the same way as previously described.

LABORATORY METHODS

Chlorophyll Analysis

Frozen filters were trimmed and ground in a glass mortar with a teflon pestle. The sample was extracted with 90% acetone in water overnight. All extractions were performed in total darkness.

The extract was centrifuged at 3000 rpm for ten minutes. The supernatant was decanted into spectrophotometer cells and the absorbance determined at 750, 663, 645, and 630 mu.

Pheophytin A was determined after acidification of the sample with 10% HCL.

Concentrations of chlorophylls and pheophytin were determined by the SCOR/UNESCO equations and method of Lorenzen, respectively.

BENTHOS

Triplicate samples from each station were washed in the laboratory to remove silt, and all organisms were sorted by hand. Each organism was mounted on microscope slide and identified to species whenever possible.

In addition to species identification and enumeration, length of each organism was recorded to the nearest 0.5 mm. Observations of sexual maturity and instar stages were also recorded.

Type specimens of each new organism were preserved for future reference, Type collections were augmented with photomicrographs. A particular effort was made to document photographically all species which were mounted on slides.

PHYTOPLANKTON ENUMERATION

Samples preserved in Lugol's solution were left undisturbed for 24 hours. This allowed sufficient time for the phytoplankton to settle to the bottom of the container. All preservative in excess of 50 ml was removed with a pipette. The sample was rinsed from the bottle into a 100 ml graduated cylinder. The sample was allowed to settle overnight again and the volume reduced to 18 ml with a pipette. The sample was stored in a 20 ml vial until counted.

After mixing the contents of the vial, a subsample was transferred to a Sedgeqick-Rafter counting chamber with a volume of 1 CC. The contents of the counting chamber were allowed to settle for 15 minutes and counted. Thirty fields, 10 on each of three counting chambers, were counted. A magnification of 100X was used for all work.

Identification was made to species whenever possible. Photomicrographs of all species were made for documentation purposes. After counting all, samples were saved for future reference and possible exchange of samples with other laboratories.

ORGANIC NITROGEN - REVISED ORION PROCEDURE

General Procedure:

1. Sample - use 500 ml of unfiltered water or 1 g. of dried, ground sediment dissolved in 500 ml double distilled water (ammonia free). Place in 1 liter wide-mouth Erlenmeyer flask.

2. Ammonia removal - add 15 ml of phosphate buffer, and boiling chips. Boil at moderate temperature until slightly less than 200 ml remains. Let cool. Add 50 ml of digestion reagent.

3. Digestion - boil sample as rapidly and as hotly as possibly; at least 340°C. Yellow-white fumes of SO_3 should be given off. Continue to boil until less than 200 ml is left.

4. Preparation - transfer sample to graduated cylinder. Make volume up to 200 ml with double distilled water. Take a 50 ml aliquot, add 40 ml double distilled water. Add 10 ml alkaline reagent. Check pH with meter, should be greater than 11.5. If sediment samples are cloudly at this point, filter through glass fiber filter in Millipore apparatus.

5. Determination - Place sample in 150 ml beaker and stir with magnetic stirrer. Read ABS millivolts using ammonia specific probe. Determine mg of ammonia from standard curve prepared from known concentrations.

6. Notes - Let sample run until the millivolt reading has stabilized. At low concentrations this could take 5-10 minutes. Keep the probe in a beaker of double distilled water between readings and wash and dry membrane carefully after each reading. Store probe in 0.1M NH_4Cl solution overnight or for longer periods.

Total Phosphorus (Stannous Chloride Method)

1. Apparatus: (to run 6 samples and a blank)

    (a) Seven 250 ml beakers
    (b) Seven 250 ml graduated separatory furnels
    (c) Seven 50 ml volumetric flasks
    (d) Pipets:
        1. Seven 25 ml
        2. Two 5 ml
        3. One 1 ml
        4. One "medicine dropper" type
    (e) Graduated cylinder, 50 ml
    (f) Two 50 ml burets, buret clamp and stand
    (g) Two hot plates (four beakers to each plate)
    (h) Safety aspirator for pipeting
    (i) Spectrophotometer, set at 625 nm, with either 1 cm cuvettes for 1.0 - 0.05 ppm or 5 cm for 0.1 - 0.002 ppm ranges.

2. Reagents:

    (a) Conc. HCl and conc. HNO_3
    (b) 3.6N H_2SO_4: carefully add 100 ml conc. H_2SO_4 to 1 liter of distilled water.
    (c) Phenophthalein indicator solution
    (d) 4.0N NaOH: dissolve 156 g. NaOH in 1 liter dis. water.
    (e) 0.2N H_2SO_4: Add 5.55 ml conc. acid to 1 liter water.
    (f) Benzene-isobutanol solvent: Mix equal volumes of benzene and isobutyl alcohol.
    (g) Ammonium molybdate reagent (I): Dissolve 25 gm. of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in 175 ml dist. water. Cautiously add 280 ml conc. H_2SO_4 to 400 ml dist. water. Cool, add the molybdate sol'n, dilute to 1 liter.
    (h) Ammonium molybdate reagent (II): Dissolve 40.1 gm of $(NH_4)_6Mo_7O_{24}\cdot 4H_2O$ in about 500 ml dist. water. Slowly add 396 ml of reagent (I). Cool, dilute to one liter.
    (i) Alcoholic sulfuric acid solution: Cautiously add 20 ml conc. H_2SO_4 to 980 ml methyl alcohol, mixing continuously.
    (j) Stannous chloride reagent (I): Dissolve 2.5 g $SnCl_2\cdot 2H_2O$ in 100 ml glycerol. Heat and stir to hasten solution.
    (k) Stannous chloride solution (II): Mix 8 ml $SnCl_2$ solution (I) with 50 ml glycerol.

3. Procedure:

(a) Place 100 ml of sample into 250 ml beaker. Add 3 ml conc. HCl and 0.5 ml conc. HNO_3 to each sample. Run a control sample with each batch using 100 ml of distilled water.

(b) Place samples on hot plates and evaporate to about 30 ml. Do NOT let the beakers go dry! Add 4 ml of 3.6N sulfuric acid and evaporate to about 3-5 ml, when the nitric acid begins to fume. Do not let the samples go to dryness. Cool, dilute with about 20 ml distilled water. Add a drop of phenophthalein and titrate with 4N NaOH to a pale-pink color. Back-titrate with o.2N H_2SO_4 until the pink just disappears. Transfer to a separatory funnel, washing with dist. water, and dilute to 40-45 ml with more distilled water.

(c) Add 50 ml of benzene-isobutanol solvent and 15 ml of molybdate (II) reagent to each sample. Close funnel and shake for 1 minute. Pipet off 25 ml of the top layer, and transfer to a 50 ml volumetric flask. Add 10-15 ml of alcoholic sulfuric acid solution to each.

(d) To each volumetric flask add 10 grops of stannous chloride (II) solution and swirl vigorously. Dilute to volume with alcoholic sulfuric acid solution and mix thoroughly.

(e) After 10 minutes but before 30 minutes, read transmittance against the blank at 625 nm.
Since the distilled water may contain a finite amount of phosphates, use a blank consisting of 25 ml of alcoholic sulfuric acid solution, 25 ml benzene-isobutanol, and 10 dreps stannous chloride (II).
Find the ppm of PO_4-P using graph prepared from standard solutions.

Notes: If the transmittance is less than 47%, immediately dilute the colored sample with alcoholic sulfuric acid until transmittance is between 47 and 97%. Multiply result by amount of dilution.

The blank sample of distilled water is run to determine the amount of contamination from the glassware. All glassware should be rinsed with a 50/50 solution of 10% HCl and 10% H_2SO_4, followed by two rinses with double distilled water, then acetone.

DETERMINATION OF CHLORINATED PESTICIDES AND PCB'S

Extraction of Water (1)

The water was filtered before a 500 ml aliquot was transferred to a 1ℓ separatory funnel. After dissolving 5g of sodium chloride in the sample, it was extracted with 100, 50, and 50 ml of petroleum ether, shaking for 30 seconds each time. Each extract was dried by passing it through anhydrous sodium sulfate. The combined extracts were evaporated almost to dryness and then diluted to an approximate volume for analysis by gas chromatography.

Extraction of Sediment and Algae

A 100g subsample was extracted for 3 minutes in a Waring blender with 200 ml of a (1+1) mixture of hexane and 2-propanol. The homogenate was filtered into a 1ℓ separatory funnel. A 500 ml portion of distilled water and 5g of sodium chloride were added to the extract. The funnel was shaken gently for 30 seconds. After the layers separated, the bottom aqueous layer was discarded. The hexane was then washed once more with distilled water. The volume of hexane remaining after the second wash was measured and recorded. The hexane was dried with anhydrous sodium sulfate and evaporated almost to dryness. The residue was taken up in 10 ml of hexane and processed through the Florisil column step.

Extraction of Fish (2)

A 50g subsample of ground fish was weighed into a blender bowl. A 100g portion of anhydrous sodium sulfate was added and the mixture was blended for one minute. The sample was extracted for 2 minutes with 150 ml of petroleum ether. The ether was decanted off through a piece of filter paper. The sample was then re-extracted twice more with 100 ml of petroleum ether each time. The combined extracts were evaporated just to dryness and the lipid content was determined. The fat was then transferred to a 125 ml separatory funnel with a total of 15 ml of petroleum ether. The ether was extracted with 4 x 30 ml of acetonitrile (previously saturated with petroleum ether), shaking 1 minute each time. The combined acetonitrile extracts were evaporated just to dryness. A 20 ml portion of hexane was added and the sample was again evaporated to dryness. The residue was taken up in 10 ml of petroleum ether and processed through the Florisil column steps.

Florisil Column (3)

A 22 mm i.d. chromatographic column was prepared by adding a plug of glass wool, 20g of Florisil, and 10g of sodium sulfate. The volumn was rinsed with 50 ml of hexane before the concentrated sediment or fish extract was added. The column was eluted with 200 ml of a 20% dichloromethane in hexane solution. When the solvent reached the top of the column, the receiver was changed and the column was eluted with 200 ml of a (50 + 0.35 + 49.65%) solution of dichloromethane and acetonitrile and hexane. Both eluates were evaporated just to dryness and taken up in an appropriate amount of hexane for analysis.

Separation of PCB's from Chlorinated Pesticides (4)

A 22 mm i.d. chromatographic column was prepared by adding a plug of glass wool and a (4 + 1) mixture of actibated siliric gel and Celite. The concentrated extract was added and the column was eluted with 250 ml of petroleum ether. When 250 ml of chrate were collected (containing possible PCB and aldrin residues), the receiver was changed and DDT and analogs were eluted with 200 ml of a (1 + 19 +

80) mixture of acetonitrile and hexane and dichloromethane. The eluates were evaporated just to dryness and taken up in an appropriate amount of hexane for analysis.

Gas Chromatographic Analysis

An aliquot of the final solution was injected into a gas chromatograph equipped with an electron capture detector. Peak areas of the sample were compared with those from standard injections to determine the amount of residue present.

Note (1)

For fish samples it is expected that the first eluate from the Florisil column will have to be put through the siluic and column to separate the PCBs from chlorinated pesticides. This separation will be used on other types of samples also if there is a hint that PCBs are present.

(2)

Sample weight for alga will probably be 10g since it was difficult to obtain a large sample.

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All biological, physical and chemical data submitted by Dr. Moore with his annual report will be in STORET by February 1, 1974 under agency code: 51IFYGL.

PLANKTONIC ROTIFERA AND CRUSTACEA
OF THE
LAKE ONTARIO INSHORE REGION

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Planktonic Rotifera of the Lake Ontario Inshore Region

by

Samuel J. Markello

Introduction

This study represents only one component of the Lake Ontario Inshore Zooplankton Survey. Information on the planktonic rotifer community of Lake Ontario was scarce prior to the recent lakewide study by Nauwerck (1972). Nauwerck cited data on the seasonal variation and relative abundance of various species averaged over three stations (Burlington Bay, central basin, eastern region).

The objectives of this study included an analysis of the effect of sampling locality (region along the shore and distance from shore) on rotifer population dynamics. Subsequent to significant findings, an analysis for underlying causes, both biotic and abiotic, will be conducted. In essence the problem involved the effect of local perturbations on zooplankton production.

Various parameters of the rotifer community should be especially sensitive to local influences. Diversity, production, and biomass of the rotifers are known to respond positively to enhanced levels of food resource and temperature in nature (Nelson and Edmondson, 1955; Hillbricht-Ilkowska and Weglenska, 1970; Patalas, 1970; Nursall and Gallup, 1971). Community-alpha, a coefficient of competition at the community level, is likewise expected to vary directly with resource levels and should be especially evident among stations at various distances from shore. In addition to the above there are species of rotifers generally agreed upon as indicators of eutrophic conditions (Pejler, 1957).

This report contains a partial assessment of the samples analysed to date. These include all surface samples (0-5M) from Cruise I (May 30-June 20), three transects (13, 14 and 15) from Cruise II, and five sampling dates for the three stations of transect 9.

Methods and Materials

Samples were taken at each of three stations (0.4, 4.0 and 8.0 kilometers from shore) on 15 transects located between the mouth of the Genesee River and Stony Point. Zooplankton were collected with a conical net (aperture 64 μ, 0.5 M diameter). Vertical hauls were taken at 5-meter intervals (0-5, 0-10, 0-15, etc.) down to 30 meters or bottom, 10 meter intervals between 30 and 50 meter depths, and 50 meter intervals thereafter.

All samples were initially treated with carbonated water (a relaxant for the organisms) and preserved with sufficient formaldehyde to yield a 4% solution.

In the laboratory, subsamples were taken and dilutions made accordingly to insure at least 50 individuals of the dominant species/count. A count of all specimens in three subsamples was found to be adequate (tested by analysis of variance) to detect differences in the major species between samples from randomly selected stations. References consulted for keying included Ahlstrom (1940, 1943), Voigt (1956), Nipkow (1957), Koch-Althaus (1963), Sudzuki (1964) and Pourriot (1965). Despite this there is uncertainty about three species, *Polyarthra dissimulans*, *Polyarthra longiremis* and *Synchaeta sp.*

Testing

To determine the effects of distance from shore (DFS) and location along shore (LAS) on density of each species, a non-parametric test was employed (Friedman's method of randomized blocks). The possibility of interaction between the fixed main effects (DFS and LAS) prohibited the use of a Model I, 2-way factorial ANOVA without replication.

To test for density differences between two specific regions (the average of transects 1, 2 and 3 versus transects 13, 14, 15) a Model I, 2-way factorial ANOVA (with transects as replicates) was utilized. The effects of time and DFS on density at transect 9 were tested with a mixed-model, 2-way factorial ANOVA.

Results and Discussion

1) General

Most species of rotifers, encountered in the inshore region of Lake Ontario on Cruise I (Tables 1-4), were likewise observed by Nauwerck (1972) in June 1970. In addition we found specimens of *Keratella crassa*, *Polyarthra major* and *Trichocerca multicrinis* occurring in June while Nauwerck observed them later in the season. Species unique to the inshore study include *Brachionus quadridentatus* (innermost station of transects 1 and 4), *Brachionus urceolaris* ("IN" of transect 1, and "IN" plus "Mid" of transect II), *Polyarthra euryptera* (transects 3, 8, 9) and *Polyarthra dissimulans* plus *P. longiremis* (occurring at all transects). The latter combined species of *Polyarthra* are difficult to separate considering overlapping sizes, identical number of ovarian nuclei and both possessing a pair of ventral appendages (Nipkow, 1957). Because of their large size the combined species of *Polyarthra* are easily distinguished from *P. dolichoptera*.

For the purposes of this study, *Keratella earlinae*, *K. irregularis* and *K. cochlearis*, *V. robusta* have been combined. Nauwerck (1972) combined the first two but kept the third separate. All three are morphologically alike with considerable overlap in body and spine lengths They are easily distinguished by the plague pattern on the empty lorica; however, most specimens taken are intact and time does not permit the close scrutiny needed to separate them.

An additional point of taxonomic significance was the presence of 14 species of rotifers during Cruise I (indicated in Table 1) which are often associated with eutrophic conditions.

Comparison of the composition of the rotifera over 12 transects (Fig. I) indicated dominance by the Synchaetidae (Synchaeta and Polyarthra) over most of sampling area. Keratella equalled the Synchaetidae at transect II (directly off the Oswego River). Nauwerck's mean data for three sampling areas in June 1970 indicated a smaller percentage of Synchaetidae (especially Polyarthra), and a greater contribution by "others." The mean density of total Rotifera (Fig. I) give one the impression of lower concentrations in the Western region of our sampling area. However, transects 11-14 were sampled earlier in June and the density difference could simply reflect overall lower production at that time.

2) Effect of location along shore (LAS) and distance from shore (DFS) on species density.

To assess (LAS) effects it is necessary to minimize time effects. This is especially important for the Cruise I data (collected between day 151 and 172 of 1972), this being the usual time of increased production. The data in Table 1 represent mean densities (for the 0-5 meter depth interval) averaged over the three stations (IN, MID and OUT) at each transect. Dividing the transects up into two groups (1-8 and 9-14) based on sampling times, and testing the variation of each species over the transects within each group, resulted in a significant LAS effect for only one species (Synchaeta lakowitziana). This species is a cold water form, absent during the summer and fall (July-November). The absence of significance for additional species is surprising, particularly when viewing the variability in densities among transects (Table I).

One difficulty in testing for LAS effects is the lack of replication at sampling stations. Thus, it was decided to combine transects and compare regions using stations of equal distance from shore as subgroup replicates within regions. The regions tested (Table 2) involved transects 1-3 (Genesee River area) and transects 13-15 (Mexico Bay). Data for the latter area were taken from Cruise II in an attempt to minimize the difference in sampling time between regions (8 days). A significantly higher mean concentration of *Asplanchna priodonta*, *Kellicottia longispina*, *Keratella earlinae* + *irreg*. + *coch*. *robusta* was found in the Mexico Bay region, while the reverse was true of *Keratella hiemalis* and *Synchaeta lakowitziana* (both cold water species).

While not significant at the 5% level, at least four other species tested had greater mean concentrations in the surface waters of Mexico Bay (*Keratella cochlearis cochlearis*, *K*. *quadrata*, *Polyarthra dolichoptera* and *P*. *vulgaris*). The two remaining, *Brachionus angularis* (a good indicator of eutrophy) and *Synchaeta stylata* had higher levels around the Genesee River area. Ecological interpretation of these differences must await analysis of the temperature and food resource data.

To assess distance from shore (DFS) effects, densities at each of the three locations (IN, MID and OUT) were averaged over 12 transects (transects with missing stations were omitted). Of the 33 species tested, only two (*Kellicottia longispina* and *Keratella cochlearis*) displayed significantly higher concentrations shoreward (Table 3). Many of the remaining species displayed a similar gradient however at a lesser degree of consistency among transects. Inconsistency suggests a possible interaction between LAS and DFS effects on density. In the absence of replicates/station interaction cannot be tested.

3) Effect of time and DFS on density

One transect was selected from which all three stations had been sampled on the same day (or within a 24 hour period) on each of five different dates. Densities reported for each date (Table 4) represent a mean over the three stations. As is readily apparent and expected, most of the species displayed significant seasonal variations over the sampling interval (June 9-September 25).

Of interest in the data is the absence of significant changes in Keratella cochlearis, a eurythermal species. This species is often known to undergo a marked decline in early to mid-summer and a resurgence in late summer. Five sampling dates may simply have been insufficient to detect the characteristic changes. Another possibility, which must be examined, is the presence of factors unique to transect 9, which permit this species to maintain its population. In the near future, data for the remaining transects will be analyzed and compared with those in Table 4.

The effect of DFS over time (for transect 9 only) was found to be non-significant for all species. It is presumed that DFS effects are dependent upon time of year.

Summary

Considering the surface samples of the southeast Lake Ontario inshore region during June 1972, we observed some 35 species of planktonic rotifers, representing 13 genera. Fourteen of the species are often found in association with eutrophic conditions. Two genera (Synchaeta and Polyarthra) comprised the bulk of the surface rotifer community.

Our data show a significant horizontal heterogeneity with respect to the density distribution of select rotifers. In general, many rotifer species displayed a density gradient of increasing concentration shoreward, although differences for only two species were statistically significant. A comparison of standing crop for 11 species, between the Mexico Bay area and the region near the Genesee River mouth, indicated seven species (three significant) with greater abundance in Mexico Bay and four (two significant) more dense around Rochester.

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Table I. Cruise I, Mean Surface Density (Number/Liter) per Transect (June 1972).

Species	Transects											
	1	2	3	4	5	6	8	9	11	12	13	14
Asplanchna priodonta	2.1	0.6	1.7	1.2	2.0	2.6	1.1	0	1.9	1.2	0.1	0.9
[1]Brachionus angularis	1.5	0.3	1.8	0.2	2.4	1.9	0.8	1.3	2.8	0.9	0.4	0.2
[1]B. calyciflorus	0.4	0.1	0.2	0	0	0	0	2.1	3.6	1.9	0	0.2
[1]B. quadridentatus	1.4	0	0	0.2	0	0	0	0	0	0	0	0
[1]B. urceolaris	0.1	0	0	0	0	0	0	0	0.7	0	0	0
Collotheca mutabilis	0	0	0	0	0	0	0	0	0	0.1	0	0
Conochilus unicornis	1.1	0.1	1.1	0.7	1.8	1.5	0.5	0.2	2.6	0.8	0.5	0.7
[1]Euchlanis dilatata	0	0	0.2	0	0	0	0	0.1	0	0	0.1	0
[1]Filinia longiseta	0.4	0.1	0.3	0.2	0	0	0	1.0	0.5	0.3	0.1	0.1
Kellicottia longispina	19.9	7.4	23.4	11.1	32.0	53.1	20.4	11.5	1.7	2.7	3.6	2.9
Keratella cochlearis cochlearis	26.4	7.6	30.6	14.6	28.4	21.5	7.9	10.8	51.9	11.2	6.3	7.4
K. earl[1] + irreg[1] + coch. robusta	33.6	14.3	34.0	18.5	34.9	77.0	46.0	27.1	26.2	4.6	8.5	8.1
[1]K. cochlearis fa. tecta	0.4	0.1	0.1	0	0.1	0	0	0.8	0	0.1	0.1	0
[1]K. crassa	1.0	0.1	0.9	0.4	1.0	0.8	0.1	0.1	1.2	0	0	0.1
K. hiemalis	0.4	0.4	1.4	0.9	0.9	0.2	0.1	4.8	2.3	1.0	0.6	0.03
[1]K. quadrata	22.7	5.6	17.4	6.8	10.8	10.4	5.8	30.3	34.4	11.0	11.6	0.9
K. quadrata v. canadensis	3.0	0.8	2.4	1.6	2.5	3.6	1.1	5.3	2.9	0	3.4	0.2
Notholca acuminata	0.1	0.1	0.03	0	0	0	0	0.4	1.4	0.2	0.2	0

Table I (continued)

Species	Transects 1	2	3	4	5	6	8	9	11	12	13	14
N. squamula	0.2	0.3	0.8	0.5	0.4	0.1	0	0.2	0.6	1.2	0.3	0.5
N. striata	0.1	0.1	0	0.1	0.03	0	0	0.1	0.1	0.2	0.3	0.1
Notholca foliacea	0.1	0	0	0.03	0.1	0.2	0	0.1	0	0	0	0
[1]Ploeosoma truncata	0	0	0	0	0	0.1	0.2	0	0	0	0	0
[1]Polyarthra euryptera	0	0	0.2	0	0	0	0.1	0.1	0	0	0	0
P. dissimulans + longiremis	6.0	0.4	4.1	2.5	9.5	15.4	1.6	8.3	3.7	2.7	13.4	1.7
P. dolichoptera	96.1	45.2	109.0	65.9	74.2	124.7	35.2	98.6	23.2	50.6	49.3	20.3
P. major	11.0	2.9	11.7	2.8	5.9	6.5	0.2	2.0	0.1	3.0	4.4	0.1
P. remata	3.9	3.7	7.8	0.8	2.7	2.4	10.0	3.5	0.2	2.9	5.9	6.5
P. vulgaris	100.6	38.9	80.4	69.0	59.0	72.1	77.1	35.7	11.3	4.6	11.7	5.0
*Synchaeta lackowitziana	1.2	11.0	9.6	13.5	4.3	4.6	2.5	51.3	75.0	81.5	54.9	41.6
S. pectinata	0.4	0.1	1.0	0	0.1	0	0	1.1	4.8	4.8	1.2	0.8
S. stylata	119.6	138.0	106.0	69.2	25.3	56.7	129.6	4.5	2.0	1.4	5.0	4.4
[1]Trichocerca multicrinis	0	0	0.2	0	0.1	0	0	0	0	0	0	0
Sampling date	166	166	167	167,168	168,172	172	171	161	151	152	158,160	158

[1] Species often associated with eutrophic conditions (Pejler, 1957; Nauwerck, 1972).

*Only species to show significant difference in density among transects (1-8), $P < .025$

Table II. A Comparison of Mean Surface Density (#/ℓ) between Regions I (Genesee River area) and II (Mexico Bay)[2].

Regions-	I	II	
Transects-	1, 2, 3	13, 14, 15	
Sampling Dates-	166-167	174	F-value
Asplanchna priodonta	1.5	6.2	11.689**
[1]Brachionus angularis	1.2	0.7	1.037^{NS}
Kellicottia longispina	16.9	55.8	9.478**
Keratella cochlearis cochlearis	21.6	44.7	2.875^{NS}
K. [1]earl. + [1]irreg. + coch. robusta	27.3	102.4	18.762***
K. hiemalis	0.7	0.04	8.945*
[1]K. quadrata	15.3	24.0	2.017^{NS}
Polyarthra dolichoptera	83.5	118.5	1.270^{NS}
P. vulgaris	73.3	146.3	2.429^{NS}
Synchaeta lakowitziana	6.5	1.6	5.857*
S. stylata	121.2	104.6	0.213^{NS}

NS - Not Significant

* - $P < 0.05$

** - $P < 0.01$

*** - $P < 0.001$

[1] Species associated with eutrophic conditions.

[2] Data for this region taken from Cruise II.

Table III. Mean Surface Density (#/ℓ) over 12 Transects.

	Cruise I			
Species	IN	MID	OUT	Chi-Square
Asplanchna priodonta	1.6	1.8	0.5	3.875^{NS}
Brachionus angularis	2.1	1.2	0.4	5.292^{NS}
Brachionus calyciflorus	1.5	0.5	0.2	1.983^{NS}
Brachionus quadridentatus	0.4	0	0	0.442^{NS}
Brachionus urceolaris	0.2	0.03	0	0.484^{NS}
Collotheca mutabilis	0.03	0	0	0.067^{NS}
Conochilus unicornis	1.5	1.2	0.3	3.875^{NS}
Euchlanis dilatata	0.1	0.02	0	0.317^{NS}
Filinia longiseta	0.5	0.2	0.1	1.733^{NS}
Kellicottia longispina	20.4	20.5	6.5	9.5**
Keratella cochlearis cochlearis	37.2	13.2	5.7	9.5**
K. earlinae + irregularis + cochlearis robusta	34.6	33.4	15.2	3.167^{NS}
K. cochlearis fa. tecta	0.4	0	0.05	2.608^{NS}
K. crassa	0.7	0.6	0.08	3.792^{NS}
K. hiemalis	0.5	1.7	1.1	0.375^{NS}
K. quadrata	21.6	12.9	7.5	3.500^{NS}
K. quadrata canadensis	3.4	2.5	0.7	4.875^{NS}
Notholca acuminata	0.5	0.1	0.1	0.442^{NS}
N. squamula	0.3	0.5	0.4	2.667^{NS}
N. striata	0.06	0.2	0.07	0.792^{NS}
N. foliacea	0.04	0.06	0.03	0.067^{NS}
Ploeosoma truncata	0	0.02	0.04	0.484^{NS}
Polyarthra euryptera	0.05	0.04	0.01	0.109^{NS}

Table III (continued)

	Cruise I			
Species	IN	MID	OUT	Chi-Square
P. dissimulans + longiremis	6.3	7.1	4.0	0.500^{NS}
P. dolichoptera	61.2	91.7	45.2	0.667^{NS}
P. major	4.1	6.1	2.4	1.792^{NS}
P. remata	5.0	5.0	2.6	4.667^{NS}
P. vulgaris	61.5	49.1	30.7	4.500^{NS}
Synchaeta lackowitziana	26.7	30.3	30.8	4.542^{NS}
S. sp. (?)	7.0	0.3	0.9	1.234^{NS}
S. pectinata	1.9	1.1	0.6	1.542^{NS}
S. stylata	50.0	78.2	37.3	4.500^{NS}
Trichocerca multicrinis	0.2	0.1	0	0.067^{NS}

NS - Not Significant

** - $P < .01$

Table IV. **Mean Surface Density Averaged Over Three Stations for Transect 9 on Each of Five Sampling Dates.**

	Date					
Species	6/9	7/5	8/7	8/31	9/25	F-value
Asplanchna priodonta	0	24.4	8.4	5.8	4.2	6.41*
Conochilus unicornis	0.2	4.7	336.1	78.1	0	17.37**
Kellicottia longispina	11.5	10.3	8.1	0.2	0.5	7.60**
Keratella cochlearis cochlearis	10.8	10.3	11.8	6.3	15.9	1.18^{NS}
K. earl. + irreg. + coch. robusta	27.1	146.4	56.5	54.9	53.2	3.89*
K. crassa	0.1	0.7	3.2	21.8	64.3	48.53**
K. hiemalis	4.8	0	0	0	0	3.46^{NS}
K. quadrata	30.3	1.5	14.3	0	0	20.23**
Ploeosoma truncata	0	0.4	3.4	86.7	20.6	28.49**
Polyarthra dolichoptera	96.6	37.6	5.1	3.5	1.6	19.63**
P. major	2.0	0.8	201.5	51.8	36.2	2.39^{NS}
P. vulgaris	35.7	138.7	480.4	1043.4	189.7	32.36**
Synchaeta lakowitziana	51.3	5.1	0	0	0	11.07**
S. stylata	4.5	72.0	4.7	18.6	21.7	9.08**
Trichocerca multicrinis	0	0	0.1	29.4	2.7	7.19**

NS - Not Significant

* - $P < .05$

** - $P < .01$

Planktonic Crustacea of the Lake Ontario Inshore Region

by

Donald C. McNaught and Daniel Giovannangelo

Introduction

In the inshore waters (<50 m) of Lake Ontario the cyclopoid copepod *Cyclops bicuspidatus thomasi* (Forbes) and the cladoceran *Bosmina longirostris* (Deevey) have been dominant since 1969. However, in 1939 *Daphnia* and *Diaptomus* spp. were relatively more abundant (McNaught and Buzzard, 1974). These changes are likely due to the accelerated cultural eutrophication of Lake Ontario.

The inshore waters are first to receive the nutrient load of tributary streams. Here such nutrients are ultimately involved in stimulating algal growth, as well as in determining the succession of dominant algal groups. Both the net production of these algal communities, as well as their species composition, influence the number and relative abundance of the species of zooplankton. Thus the zooplankton reflect changes in lake ecosystems usually considered only in terms of the algae.

Such changes in zooplankton composition have been recorded in the literature for Lake Ontario. Seven investigations since 1912 have detailed changes in the crustacean zooplankton, but largely ignore the rotifers. Recent basinwide studies by Patalas (1969, 1972) and Carpenter *et al*. (1972) describe extensive collections made by investigators from CCIW in 1968 and 1970. Limited useful collections were made near Rochester by Whipple (1913) in 1912 and Tressler *et al*. (1940) in 1939. The discovery of a brackish-water calanoid copepod was reported by Anderson and Clayton (1958). McNaught and Fenlon (1972) took limited inshore samples in the Oswego area in 1969 and

1970. Generally, then, the zooplankton of Lake Ontario are well-known taxonomically, but little is known of their feeding habits, predators, and especially the response of such populations to pollutants.

The purpose of this study is to identify inshore areas of Lake Ontario which exhibit perturbation of the zooplankton community. We have employed two distinct approaches in the analysis of our data. First, the densities of organisms have been compared with respect to the distance from shore (DFS) at which samples were collected. Secondly, after determining the relative densities of all taxa, the sample means have been subjected to community analysis.

Community Theory

Two basic assumptions underlie the use of niche theory (Levins, 1968) to predict the maximum theoretical carrying-capacity of an aquatic environment. First we have assumed that crustaceans exhibit sigmoid growth in nature, and that the concept of an environmental carrying capacity is real for them. Secondly, we have assumed that with community development, a likely evolutionary strategy includes the reduction of interspecific competition, i.e. a reduction of the mean community competition coefficient (α).

Assuming that crustacean populations continually push against an ever changing carrying-capacity, we must first estimate the competition coefficient (Levins, 1968):

$$\alpha_{2 \cdot 1} = \frac{\sum_{h=1}^{n} P_{1h} P_{2h}}{\sum_{h=1}^{n} P_{1h}^2} \tag{1}$$

where h is an environment and P_1 and P_2 are the proportion of species 1 and species 2. This alpha assumes that competition for resources is proportional to the probability of occurrence in an environment h (Lane and McNaught, 1970, 1973). Then, from the logistic:

$$(2) \qquad \frac{dN_1}{dt} = r_1 N \left(\frac{K_1 - N_1 - \alpha_{2\cdot 1} N_2}{K_1}\right)$$

where r_1 is the instantaneous growth rate of species 1, we can calculate the maximum theoretical carrying capacity (K_1) for species 1, where:

$$(3) \qquad K_1 = N_1 + \sum_{2=1}^{m} \alpha_{2\cdot 1} N_2$$

This maximum carrying-capacity is the maximum density which a species would obtain if no competitors were present, where the calculation is made with an assumption of steady-state ($\frac{dN_1}{dt} = 0$).

Likewise it is possible to estimate the total number of species the community will hold from the covariance of alpha (Levins, 1968). In general, when the variance of alpha (Tables 2-3) is small the community is predicted to hold more species, as indicated by the ratio observed: theoretical number.

Finally, Shannon-Weaver species diversity values were determined for inshore and offshore waters for the years 1969-1972, where:

$$(4) \qquad H = -\Sigma p_i \log_e p_i$$

where p_i = proportion of all species belonging to the ith species.

Methods

Samples were collected as in the concurrent study of the rotifers (Part I). In the laboratory approximately 100 individuals of the dominant species were counted from each sample.

To determine significant differences in distribution with regard to distance from shore, we used an unpaired t-test.

Results and Discussion

(1) General trends

The inshore community was dominated from May through July 1972 by *Cyclops bicuspidatus* and, most likely, the copepodites of this cyclopoid copepod, as well as by *Bosmina longirostris* (Table V). *Diaptomus* (*minutus* + *sicilis*), *Limnocalanus macrurus* and calanoid copepodites were of secondary importance. *Chydorus sphaericus* was common inshore in May and June of 1972. This chydorid is interesting because of its habit of hitch-hiking on buoyant colonies of blue-green algae. *Daphnia* (*galeata* + *retrocurva*), *Tropocyclops prasinus* and *Eurytemora affinis* were relatively uncommon (less $60/m^3$).

(2) Effect of distance from shore (DFS) on species density

The effect of distance from shore (DFS) on species density for crustacean zooplankton was assessed for cruises I and II over the three stations (IN, MID, OUT) using an unpaired t-test (Table VI). From Table V it would appear that many species are more abundant near shore (IN). However, only *Tropocyclops prasinus* exhibited a significant difference ($p < .05$) when IN densities were compared to OUT for cruise I.

Generally we conclude that the planktonic crustaceans do not show significantly higher concentrations shoreward within our narrow zone of study.

(3) Community analysis

The community competition coefficient (α), the theoretical carrying capacity (K) and the ratio of the observed density: theoretical carrying capacity (N/K) provide insight into community interactions sensitive to pollution.

Alpha is an index of potential interspecific competition (Table VII). It is a valuable index in itself. In these preliminary data we see evidence that interspecific competition is potentially greatest in MID shore areas. But the chief reason for calculating alpha is to approximate the theoretical carrying-capacity (K).

Theoretical community carrying-capacity (K) for planktonic crustaceans should be responsive to available food resources. In the cases of cruises I and II the theoretical carrying capacity is greatest in the IN shore locations. These data signify that something is accounting for such high densities (N) and carrying-capacities (K). We suggest initially that a high K is indicative of community perturbation.

If the theoretical carrying-capacity is large, and it is actually realized on a relative basis (N/K), this provides additional evidence of perturbation. For example, in the case of cruise I, the OUT stations had a predicted capacity of 74,778 animals/m^3 and 15% of this capacity was realized (N/K), the maximum for the two cruises discussed. In the final analysis of our data we will use a combination of K and N/K to indicate the probable degree of perturbation of a given community. Presently we can state that the N/K ratio for this Oswego sector (this study) ranges from .08 to .15 and this range is similar to the lake-wide range of .07 to .24 (McNaught and Buzzard, 1974).

Summary

The crustacean zooplankton of the inshore waters of Lake Ontario near

Oswego are dominated in summertime by Cyclops bicuspidatus and Bosmina longirostris. At present we find no evidence that these dominant forms are at significantly higher concentrations as we proceed shoreward. However, the theoretical carrying capacity of such populations is greatest close to shore. The extent to which this carrying capacity is realized is greatest farther off shore (OUT stations). In the future, should the theoretical carrying-capacity and the degree to which it is realized both reach a maximum inshore or near sources of high nutrient input, we will have evidence for community perturbation.

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Table V. Mean Density of Organisms with Respect to Distance from Shore (DFS) for Cruise I (May 30, 1972–June 22, 1972) and Cruise II (June 22, 1972–July 6, 1972).

Species/location	#/m^3 (Cruise I)	#/m^3 (Cruise II)
Bosmina longirostris		
IN	2,798	6,982
MID	1,530	5,611
OUT	447	3,125
Daphnia galeata		
IN	48	24
MID	2	33
OUT	1	1
Daphnia retrocurva		
IN	21	13
MID	2	3
OUT	1	6
Ceriodaphnia lacustris		
IN	1	151
MID	4	72
OUT	1	10
Chydorus sphaericus		
IN	913	144
MID	95	94
OUT	18	121
Cyclopoid copepodite		
IN	15,225	4,616
MID	15,987	3,406
OUT	3,912	5,675
Cyclops bicuspidatus		
IN	9,462	3,162
MID	925	880
OUT	461	2,049
Tropocyclops prasimus		
IN	1	57
MID	37	86
OUT	35	92
Calanoid copepodite		
IN	126	148
MID	148	108
OUT	99	133
Diaptomus minutus		
IN	61	82
MID	31	50
OUT	9	53
Diaptomus sicilis		
IN	0	22
MID	0	6
OUT	1	4

Table V (continued)

Species/location	#/m^3 (Cruise I)	#/m^3 (Cruise II)
Limnocalanus macrurus		
IN	28	2
MID	398	52
OUT	252	24
Eurytemora affinis		
IN	0	9
MID	0	0
OUT	1	0
Nauplii		
IN	8,798	3,070
MID	10,598	2,466
OUT	7,529	6,137

Table VI. A Comparison of Mean Density ($\#/m^3$) as an Effect of DSF for Locations IN, MID, and OUT.

Organism	t_{05} Cruise I IN vs MID		t_{05} Cruise I MID vs OUT		t_{05} Cruise I IN vs OUT		t_{05} Cruise II IN vs MID		t_{05} Cruise II MID vs OUT		t_{05} Cruise II IN vs OUT	
Bosmina longirostris	.7582	NS	2.0108	NS	1.3807	NS	.3849	NS	1.7408	NS	1.4452	NS
Daphnia galeata	1.0170	NS	.7334	NS	.9981	NS	.3407	NS	1.3798	NS	1.8586	NS
Daphnia retrocurva	1.1182	NS	.4489	NS	1.0151	NS	.7776	NS	.4293	NS	.5011	NS
Ceriodaphnia lacustris	.8005	NS	1.0062	NS	.4636	NS	.5391	NS	1.0477	NS	1.0987	NS
Chydorus sphaericus	1.0123	NS	1.5443	NS	1.1156	NS	.9015	NS	.2221	NS	.3420	NS
Cyclopoid copepodite	.0552	NS	1.1107	NS	1.238	NS	.7774	NS	1.0683	NS	.3410	NS
Cyclops bicuspidatus	1.0211	NS	1.1593	NS	1.4974	NS	1.7480	NS	1.2378	NS	.4851	NS
Tropocyclops prasimus	2.1632	NS	.1123	NS	2.4528	*pc .05	.6562	NS	.5044	NS	1.0134	NS
Calanoid copepodite	.1899	NS	1.3657	NS	.5064	NS	.8609	NS	.1068	NS	.3356	NS
Diaptomus minutus	.8373	NS	1.2657	NS	1.5770	NS	.6544	NS	.0893	NS	.4880	NS
Diaptomus sicilis							.7751	NS	.3219	NS	.8243	NS
Limnocalanus macrurus	.9497	NS	.3355	NS	1.1209	NS	1.7658	NS	.9503	NS	1.9387	NS
Eurytemora affinis			1.0000	NS	1.0427	NS						
Nauplii	.3040	NS	.6817	NS	.2556	NS	.3131	NS	1.2965	NS	.9277	NS

Table VII. Community Analysis for Crustacean Zooplankton.

	Total Number (#/m^3) of Zooplankton (N)	Alpha (Variance)	Observed Species/ Theoretical Species	Theoretical (K) Carrying Capacity (#/m^3)	N/K	Diversity
Cruise I						
IN	34,606.05	.318 (.161)	14/5	408,397	.085	1.79
MID	29,107.54	.345 (.130)	14/6	222,221	.13	1.73
OUT	11,399.86	.265 (.076)	14/7	74,778	.15	2.16
Cruise II						
IN	20,439.6	.333 (.076)	14/7	222,959.1	.09	2.48
MID	12,994	.416 (.118)	13/6	110,769	.12	2.23
OUT	20,344	.360 (.147)	14/6	171,916	.12	2.50

ANNUAL REPORT
ANALYSIS AND MODEL OF IMPACT OF DISCHARGES FROM NIAGARA AND GENESEE RIVERS OF THE NEAR-SHORE ZONE

Sponsored by

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to

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I. INTRODUCTION

The objectives of the U.S. Environmental Protection Agency (EPA) sponsored multi-year project, which is part of the International Field Year on the Great Lakes (IFYGL), are as follows:

a. To formulate a model that could be employed in the prediction of ecological responses to inputs in the near-shore region of large lakes.

b. To ascertain the nature, extent and interactions on inputs, including pollutants, on the aquatic biological and chemical processes in the near-shore region of Lake Ontario.

c. To evaluate the rate of flow of nutrients into, out of, and within the study area, including movements between aquatic and benthic habitats.

d. To examine the role, if any, of a thermal bar on nutrient transport and recycling, as well as a biological barrier.

e. To develop an ecological baseline that could be of value in the evaluation of the impact of proposed developments (i.e., sewage treatment plants, electric power generating stations, etc.) along the Lake Ontario shoreline and tributaries, as well as in the determination of the present status and rate of eutrophication of Lake Ontario.

f. To measure the extent of Cladophora growth and factors which influence the morphology of this area. Emphasis will be directed toward the formulation of means through which the problems caused by this plant can be reduced.

This report details the plans and accomplishments by the staff of the Great Lakes Laboratory (GLL) on the above project during the period from 1 April 1972 through 31 March 1973. The majority of the GLL's efforts in 1972-73 were concerned with the collection of biological and chemical samples as well as making physical measurements in the study zone. The latter consisted of an area eight (8) kilometers wide (as measured from the shore into the lake) and extending in length from the Welland Canal through Rochester. Forty-five (45) near-shore stations were established. These were situated one-half (1/2), four (4) and eight (8) kilometers from shore along lines ten (10) kilometers apart. In addition twenty-four (24) and twelve (12) stations were located in the mouths and plumes of the Niagara and Genesee Rivers respectively. The number and location of each of the stations is shown in Table I. Collection sites for Cladophora were established at five (5) locations along lines extending into the lake and perpendicular to the shore. The location of the intersection of these lines and the shore is given in Table II. Sampling of the attached alga was conducted along the line in water depths of 1, 2, 3, 4, 5 and 6 meters.

TABLE I

Near-Shore and River Mouth

COLLECTION STATIONS

Near-Shore Zone

Station #	Longitude	Latitude
201	79°13'48"	43°13'26"
202	79°13'48"	43°15'24"
203	79°13'48"	43°17'36"
204	79°06'54"	43°15'48"
205	79°07'36"	43°17'42"
206	79°07'18"	43°19'48"
207	79°01'18"	43°16'48"
208	79°01'48"	43°18'36"
209	79°02'30"	43°20'36"
210	78°54'12"	43°18'18"
211	78°55'00"	43°20'06"
212	78°55'48"	43°22'12"
213	78°47' 6"	43°18'48"
214	78°47'48"	43°21'36"
215	78°48'36"	43°23'42"
216	78°39'48"	43°21'18"
217	78°40'36"	43°23'06"
218	78°41'30"	43°25'06"
219	78°32'36"	43°22'24"

Table I, continued

Near-Shore Zone

Station #	Longitude	Latitude
220	78°33'00"	43°24'12"
221	78°33'30"	43°26'24"
222	78°25'12"	43°22'48"
223	78°25'24"	43°24'36"
224	78°25'36"	43°26'48"
225	78°17'36"	43°22'36"
226	78°17'36"	43°24'30"
227	78°17'36"	43°26'36"
228	78°10'18"	43°22'36"
229	78°10'30"	43°24'30"
230	78°10'48"	43°26'36"
231	78°02'48"	43°22'30"
232	78°02'36"	43°24'24"
233	78°02'24"	43°26'30"
234	77°55'30"	43°21'48"
235	77°54'54"	43°23'36"
236	77°54'18"	43°25'42"
237	77°48'12"	43°20'48"
238	77°47'48"	43°22'36"
239	77°47'12"	43°24'48"
240	77°41'18"	43°18'30"
241	77°39'54"	43°19'54"
242	77°38'06"	43°21'36"
243	77°35'30"	43°15'18"
244	77°33'54"	43°16'48"
245	77°32'18"	43°18'42"

Table I, continued

Genesee River Mouth

Station #	Longitude	Latitude
351	43°15'58"	77°35'54"
352	43°15'53"	77°35'48"
353	43°16'10"	77°36'02"
354	43°16'01"	77°35'42"
355	43°15'55"	77°35'19"
356	43°16'33"	77°36'29"
357	43°16'30"	77°36'07"
358	43°16'20"	77°35'41"
359	43°16'08"	77°35'21"
360	43°15'54"	77°34'58"
361	43°15'37"	77°34'36"
362	43°16'28"	77°35'30"

Niagara River Mouth

Station #	Longitude	Latitude
363	79°05'24"	43°16'00"
364	79°05'06"	43°15'55"
365	79°05'08"	43°16'10"
366	79°04'45"	43°15'50"
367	79°04'50"	43°16'06"
368	79°04'50"	43°16'20"
369	79°04'26"	43°15'40"
370	79°04'24"	43°16'00"

Table I, continued

Niagara River Mouth

Station #	Longitude	Latitude
371	79°04'35"	43°16'15"
372	79°04'10"	43°16'30"
373	79°04'15"	43°15'45"
374	79°04'10"	43°15'46"
375	79°04'10"	43°16'20"
376	79°04'08"	43°16'35"
377	79°04'05"	43°15'46"
378	79°04'05"	43°16'05"
379	79°03'56"	43°15'47"
380	79°03'50"	43°16'15"
381	79°03'45"	43°16'35"
382	79°03'40"	43°15'55"
383	79°03'25"	43°16'08"
384	79°03'23"	43°16'30"
385	79°03'10"	43°16'20"
386	79°02'50"	43°16'10"

TABLE II

CLADOPHORA COLLECTION STATIONS

Station #	Longitude	Latitude
207	79°01'18"	43°16'18"
216	79°39'48"	43°20'48"
222	79°25'12"	43°22'18"
228	79°10'18"	43°22'06"
237	77°48'12"	43°20'18"

Between 1 April 1972 and 31 March 1973 a total of ten (10) near-shore, eight (8) Genesee river and six (6) Niagara mouth and six (6) *Cladophora* sampling runs were conducted. The dates of the above are shown in Table III.

TABLE III

COLLECTION DATES

Niagara River
Near-Shore

Run #	Julian Dates	Gregorian Dates
1	109-124	18 Apr.-3 May
2	131-144	10 - 23 May
3	171-180	19 - 38 June
4	194-203	12 - 21 July
5	207-215	25 July - 2 Aug.
6	340-347	5-12 December

TABLE III, continued

Genesee River

Run #	Julian Dates	Gregorian Dates
1	151-153	30 May - 1 June
2	156-157	4-5 June
3	157-158	5-6 June
4	158-159	6-7 June
5	164-165	12-13 June
6	235-237	22-24 August
7	241-242	28-29 August
8	332-333	27-28 November

Cladophora

Run #	Julian Dates	Gregorian Dates
1	172-180	20-28 June
2	193-202	11-20 July
3	209-214	27 July - 1 Aug
4	221-230	8-17 August
5	292-301	18-27 October

It should be noted that a total of eleven (11) near-shore, twelve (12) river mouth and five (5) *Cladophora* sampling runs had been planned. However, due to a combination of problems including delayed funding of the project, inclement weather and minor mechanical difficulties with the major research vessel, the sampling program had to be reduced. All sampling runs undertaken were completed with the exception of the 11-14 December collection that had to be curtailed after twenty-two (22) stations due to severe icing and wave conditions.

Since the overall project consisted of biological, chemical and physical components, each of the latter will be discussed separately.

II. BIOLOGICAL STUDIES

A. Phytoplankton

1. Objectives

This phase of the field survey was designed to ascertain the nature and extent of primary productivity in the near-shore zone as well as impacts of temperature stratification, as a result of the presence of thermoclines and thermal bars, and tributaries, particularly the Niagara and Genesee Rivers, on these processes. The relationship between the quantity and quality of the algae and the physical and chemical conditions in the collection areas also was to be measured.

2. Plans vs. Accomplishments

Phytoplankton was collected at each near-shore and river mouth station at 1, 5, 20, 25, 35 and 50 m meters below the surface (depth permitting) using a 4.1 liter vertical Van Dorn (Alpha) Water Sampler. One (1) liter of each sample was preserved with Lugol's solution. Fifty (50) milliliters subsamples of each are being examined for algae using the inverted microscope method of Utermöhl. Species composition as well as cell numbers and biovolume are being calculated. This enumeration procedure as well as the taxonomy being employed is being done in cooperation with Dr. M. Munawar of the Canada Centre for Inland Waters, who is conducting a similar study of the phytoplankton collected in other sections of Lake Ontario.

The initial plan was to count all the samples. However, since the phytoplankton cannot be counted in less than two (2) hours per sample, it was necessary to limit the initial analyses to the algae collected at depths of 1 and 5 meters at near-shore stations 201, 202, 203, 207, 208, 209, 213, 214, 215, 222, 223, 224, 231, 232, 233, 237, 238, 239, 243, 244, 245. In addition the phytoplankton gathered at 20, 25, 35 and 50 m also is being counted at the stations whose numbers are underlined in the above list. This reduction will provide sufficient information for the near-shore model.

A preliminary examination also is being made to ascertain if the number of river mouth stations can be limited without having a negative impact on the validity of the model.

Quantity and quality of phytoplankton vs. water chemistry cannot be undertaken until the latter is put in the STORET system by EPA.

3. Status

All 2600 samples were collected and preserved. Analyses of the representative stations from the April through July 1972 cruises have been completed. Approximately five (5) weeks effort by two (2) full-time individuals is necessary to complete the examination of a cruise. Therefore the analyses of the algae gathered during the ten (10) cruises in 1972 will be completed in early December 1973. The river mouth collections will be done by the early spring 1974.

4. Summary of Results

During Cruise I the diatoms comprised approximately 58% of algae at each station. The dinophyceans and cryptophyceans made up 22 and 18% respectively of the biomass, while Chlorophyta comprise 2% and Cyanophyta less than 1%. By July the diatoms decreased in number. They were replaced by cryptomonads and colorless bi-flagellates. The taxonomic composition of the summer flora will be discussed in a later section of this report.

The dominant species in Cruises I and II are shown in Table IV.

TABLE IV

DOMINANT PHYTOPLANTONIC SPECIES

Cruises I and II

Asterionella formosa	Hasal.
Cryptomonas erosa	Ehrenbg.
Gymnodinium helvitica	Pennard.
Melosira binderana	Kg.
Melosira islandica ssp helvitica	O. Müller
Peridinium aciculiferum	Lemm.
Rhodomonas minuta	Skuja
Scenedesmus bijuga	(Turpin) Langerheim
Stephanodiscus hantzschii	Grun.
Stephanodiscus tenuis	Hust.
Surirella angustata	Kuetz

The largest concentrations of algae by biovolume observed in the 1 and 5 meter collections from Cruise I and II collections were found inshore of the thermal bar. This is shown in Table V.

TABLE V

AVERAGE PHYTOPLANKTON IN SURFACE WATERS

(#μ^3 x 10^3/ml)

Cruise	Dates	Distance from Shore		
-		1/2 km	4 km	8 km
I	15 Apr.-3 May	1541	946	617
II	10-23 May	2866	2167	593
III	12-21 July	569	936	650

During Cruise I the thermal bar generally was found from 1/2 to 3-1/2 km from shore; during Cruise II the bar was observed primarily between 4 to 7 km from shore. By Cruise III the bar was lakeward of the 8 km station. It should be noted that while there appears to be a large number of algae at the 4 km stations in Cruise III (Table V), there was variation in the range of algal numbers from transect to transect, which was not observed in the Cruise I and II collections.

The data from the vertical profiles from Cruises I and II indicated that higher concentrations of algae were found in the waters having a temperature higher than 4°C on the shoreward side of the thermal bar.

Phytoplankton counts from the spring cruises were fairly uniform throughout a given depth profile.

By Cruise IV a thermocline had become established. The larger algal concentrations were found above the thermocline, specifically in the collections from depths of 5 meters. The distribution pattern of algae with depth as measured on the Cruise IV samples is shown in Table VI.

TABLE VI

ALGAL BIOMASS VS. DEPTH

FOR CRUISE IV

Depth	Biomass
1 m	898 $\mu^3 x 10^3/ml$
5	1115
20	558
35	653
50	618

Unlike Cruises I, II and III, the species composition varied with depth in Cruise IV. In the latter diatoms were almost absent in the collections from 1, 5 and 20 m below the surface, but at 35 and 50 m. *Melosira islandica* and *M. binderina* were a substantial fraction of the biomass.

The dominant species collected during Cruise IV were *Cryptomonas erosa*, *Rhodomonas minuta* and a variety of as yet unidentified colorless biflagellates. These organisms were found in the epilimnion.

In the spring the Niagara River with 412 $\mu^3\text{x}10^3$/ml had considerably less phytoplankton than the receiving waters which averaged 1035 $\mu^3\text{x}10^3$/ml. Sampling along the plume as it mixed with the lake, the algal numbers and variety increase with distance from the river mouth. By Cruise IV (12-21 July) the quantity and quality of phytoplankton in the plume was very similar to the collections from the 1/2 km stations.

The April collections from the Genesee River mouth, which averaged 1206 $\mu^3\text{x}10^3/\text{m}^3$, did not differ appreciably from the near-shore stations. Algal biomass decreased with increased distance from the mouth of the river. The shallowest stations yielded the highest algal concentrations.

B. Zooplankton

1. Objectives

The purposes of this aspect of the overall study were to contribute to the understanding of productivity and water quality in the Welland-Rochester near-shore zone. This was to be accomplished through the identification and enumeration of planktonic crustaceans utilizing the techniques developed by Dr. Andrew Robertson.

2. Plans vs. Accomplishments

While a total of 825 zooplankton collections were taken by means of a vertical haul of a 1/2 meter plankton net, at each near-shore and river-mouth station on every cruise, the Project Director and Mrs. Sharon Czaika, the individual doing the analysis, believe that it is not possible to examine every collection due to the time necessary to accomplish this task. On the near-shore stations, the zooplankton from every other transect is being analyzed beginning with stations 201, 202 and 203. This means that collections from a total of twenty-one (21) stations per cruise will be quantitatively and qualitatively analyzed. (It should be emphasized that this type of examination is more than sufficient to provide the inputs necessary for the development of the model. If time permits and/or if results from the chemical analyses dictate, an examination of the collections from the "in-between" stations will be made.

The only change in techniques has been the use of a Hansen-Stempel Pipette instead of a Folsom Plankton Splitter.

3. Status

The zooplankton analysis was late in starting due to the lack of agreement on taxonomy and quantification procedures. However, this matter has been remedied largely through conferences between researchers at the Canada Centre for Inland Waters and the Great Lakes Laboratory.

The zooplankton from Cruise I of the Genesee River mouth is finished. Near-shore Cruises I and II also are nearly complete with the exception that bosminids will be saved and identified at the end of the study when a sufficient variety of instars will be available.

4. Summary of Results

A summary of these initial results from the Genesee River Cruise I are as shown in Table There was little difference between the stations with respect to the quality and quantity

TABLE VII

ZOOPLANKTON - CRUISE I - Genesee

Genesee River

Taxonomic Group - Comments	% of Individuals
COPEPODS:	1.4
Calanoids:	
Diaptomus siciloides - dominant species	
Diaptomus oregonensis	
Diaptomus reighardi	
2 anomalous groups	
Cyclopoids:	15.0
immatures - most abundant	
Cyclops bicuspidatus thomasi - dominant species	
Tropocyclops prasinus mexicanus	
Cyclops vernalis	
Eucyclops prinophorus	
Herpacticoids: *Canthocamptus robertcokeri*	1.2
Nauplii	76.5
CLADOCERANS:	6.0
bosminids - dominant species	
Chydorus sphaericus	
Daphnia (2 species) - rare and in only 1/2 samples galeata mendotae retrocurva	
Alona costata - rare and in only 1 sample	
Alona guttata - rare and in only 1 sample	
	100.0%

of organisms. The only quantitative difference was the fact that twice as many individuals were found at station #354, which is approximately 700 meters northeast of the river entrance and in the middle of the Genesee River plume.

A list of species was submitted to EPA in Gaithersburg, Maryland, for their use in setting up the STORET system to accept these data.

C. Benthos

1. Objectives

The objectives of the quantitative and qualitative analyses of benthic macroinvertebrates essentially was the same as those for phytoplankton and zooplankton.

2. Plans vs. Accomplishments

Benthos was collected during 1972 on Near-shore Cruises I (18 April - 3 May), III (19 - 28 June), VI (5 - 13 September) and IX (6 - 22 November). Genesee River mouth samplings occurred on Cruises I (30 May - 1 June), V (12-13 June), VI (22 - 24 August) and VIII (27-28 November); benthos from Niagara River mouth sites were collected during Cruises I (29 May - 5 June), III (12 - 16 June), IV (21 - 26 August) and

VI (5-12 December). While attempts were made to obtain a sample at each collection site the rocky nature of the bottom precluded collections being made at near-shore stations 201, 204, 207, 210, 213, 216, 219, 222, 225 and 237. While each of the Genesee River mouth sites were collected, no benthos could be gathered at stations 366, 369, 371, 375, 378, 379, 380, 382 and 383 in the Niagara River mouth. A total of 310 stations were sampled. One (1) Ponar grab was taken at each on the collections through August, 1973. After August three (3) separate Ponar hauls were made at each site.

The use of an Ekman Dredge was terminated after the initial cruise due to the fact that collections with this device could be gathered at less than at a third of sites where Ponar collections could be made.

3. Status

The 1972 samples will be completed by December, 1973. The necessity of splitting the samples due to the large volume of organisms has delayed the project by approximately three (3) weeks.

4. Summary of Results

The majority of organisms found at the 1/2 and 4 km stations in the near-shore zone are tubificids, sphaerids and chironomids which are found in nearly equal abundance but average less than a fifth of the number of sludge worms. A few gastropods and some crustaceans also were observed. There was relatively little difference between the collections at the 1/2 and 4 km stations.

The most abundant organisms at the 8 km stations were Mysis and Pontoporeia. Oligochaetes and sphaerids also were present.

The benthic environment of the river mouths were dominated by oligochaetes. There was substantial differences between both stations in a single cruise and between the same stations sampled during different cruises.

D. Cladophora

1. Objectives

Purpose of this aspect was to ascertain the mass, in terms of wet, dry and ash weights, of Cladophora collected at different depths (1, 2, 3, 4, 5 and 6 meters) along five (5) transects extending from the shore into the lake. Another objective was to provide ground truth for the quantification of this attached alga by remote sensing.

2. Plans vs. Accomplishments

Six (6) samplings of up to six (6) collection sites along five (5) transects had been planned.

These transects were adjacent to stations 207, 216, 22, 228 and 237. However, high winds and waves, which made collecting the _Cladophora_ by SCUBA techniques impossible, resulted in the cancellation of some of the _Cladophora_ runs. The dates when collections were made per station is shown in Table VIII.

TABLE VIII

CLADOPHORA COLLECTIONS

Transect	Julian Date	Remarks
207	172	No _Cladophora_ at 1 and 2 m
"	179	" " " 1 m
"	193	" " " 1 m
"	209	" " " 1, 2 and 3 m
"	221	" " " 1, 2 and 3 m
"	292	" " " 1 and 2 m
216	173-175	High wind + waves - no collection
"	177-178	" " " " "
"	195	No _Cladophora_ at 1 m
"	223	" " " 1,2,4,5 and 6m
"	297	" " " 1,2,5 & 6 m
222	178	-
"	196	-

Table VIII continued

Transect	Julian Date	Remarks
"	209	-
"	223	No *Cladophora* at 1,2 & 3 m
"	230	" " at 1 & 2 m
"	301	" " 1 m
228	179-180	High winds + waves, no collection
"	201	-
"	213	No *Cladophora* at 1 m
"	225-277	High winds + waves, no collection
"	302-305	" " " " "
237	173-175	High winds + waves, no collection
"	180	No *Cladophora* at 1 & 2m
"	202	" " at 1,2 and 4 m
"	214	" " 1,2 and 3 m
"	230	" " 1 m
"	303	High winds + waves, no collection

Sand comprised the sediment of depths at which *Cladophora* consistently did not grow. During the latter collection dates wave action had swept away.

3. Status

The *Cladophora* collections and analyses (dry, ash and wet weights) have been completed. Directions for entering these data in STORET are being awaited.

4. Summary of Results

Cladophora growth was not found on sand or other unconsolidated strata. Also development was limited in depths of 1 to 2 meters due to wave action which broke the filaments and/or held fasts.

The changes in the percent dry, fixed and volatile weights of the *Cladophora* collected on different dates in randomly selected square foot sections of the bottom is shown in Table IX. The dry weight was observed to generally increase in the spring, reached a maximum in late July-early August and decrease again in the fall. The fixed and dry weight, on the other hand, showed no consistent pattern.

Cladophora growth will be correlated with the nutrient levels when the latter data becomes available.

TABLE IX

CLADOPHORA WEIGHTS

Station	Date	Dry Weight	Fixed Weight	Volatile Weight
207	172	13.79%	42.85%	57.15%
"	179	13.47	52.40	47.60
"	193	18.76	47.72	52.28
"	209	18.92	42.91	57.09
"	221	35.94	73.91	26.09
"	292	15.72	82.96	17.04
216	195	22.95	57.55	42.45
"	209	19.16	49.68	50.32
"	223	34.80	26.80	73.20
"	297	19.50	61.30	38.70
222	178	29.30	65.02	34.98
"	196	13.44	35.11	64.89
"	209	20.65	45.71	58.29
"	223	29.52	64.89	35.11
"	230	22.98	36.83	63.17
"	301	24.77	68.77	31.21
228	201	21.54	43.16	56.84
"	213	24.90	46.31	53.69
237	180	18.67	41.02	58.98
"	202	22.12	47.24	52.76
"	214	22.67	28.15	71.85
	230	14.09	22.65	77.35

E. Chlorophyll-a

1. Objectives

The chlorophyll-a data were gathered in order to augment the phytoplankton data regarding primary productivity in the near-shore and river mouth study areas.

2. Plans vs. Accomplishments

As proposed samples for chlorophyll-a analyses were collected at each time and depth that a phytoplankton sampling was made.

3. Status

The samples have been collected.

At the request of EPA, the raw data from the spectrophotometric analysis of chlorophyll-a were forwarded to Grosse Ile for entry into STORET. Once the latter was complete the final values for chlorophyll-a were to be calculated by the STORET computer. To dat these data were not retrievable.

4. Summary of Results

Awaiting print-out of raw data from STORET.

III. CHEMICAL STUDIES

A. Sediments

1. Objectives

The purposes of this phase of the study were to ascertain the chemical quality of the sediment in the Welland-Rochester near-shore zone and in the mouths of the Genesee and Niagara Rivers and to measure changes that occur in those benthic environments during the duration of the Field phase of IAGLR. These data were to be contrasted with the quantity and quality of benthos as well as the chemical conditions of the water above the bottom.

A total of thirty-three (33) parameters were to be measured on each sample including: nitrate, ammonia, organic and total nitrogen; suspended and dissolved phosphorus; total, fixed and volatile solids; total organic carbon (TOC) and total inorganic carbon (TIC); pesticides (DDT, DDE, DDD, lindane, aldrin, dieldrin, toxaphene, chlordane, endrin, heptochlor and heptochlor expoxide); heavy metals (iron, manganese, copper, zinc, lead, mercury, magnesium, chromium, nickle and cadmium); polychlorobiphenyls (PCB's)

2. Plans vs. Accomplishments

Sediment samples were collected with a Ponar Dredge during near-shore Cruises I (18 April - 3 May), III (19-28 June), VI (5-13 September) and IX (6-22 November). Niagara River mouth samples were taken during Cruise I (29 May - 5 June), IV (21-26 August) and VI (5-12 December). The Genesee River mouth sediment was gathered during Cruise I (30 May - 1 June), V (12-13 June), VI (22-24 August), and VIII (27-28 November). An attempt was made to obtain a sediment sample at every station. However, the nature of the bottom (rock or hard-pan) prevented material from being taken from Near-shore stations 204, 207, 210, 213, 216, 219, 222, 225 and 237, as well as Niagara River stations 366, 369, 371, 375, 378, 379, 380, 381, 382 and 383.

With regards to chemical analysis, a measurement of dry weights were added to the test for solids. Samples for pesticide and PCB analyses were sent to the Lake Ontario Environmental Laboratory (LOTEL) of the State University College at Oswego. In exchange the GLL made qualititative and quantitative tests for the ten (10) heavy metals listed above on sediment samples collected by LOTEL.

3. Status

All sediment samples gathered during 1972 in the Welland-Rochester Near-shore zone as well as in the mouths of the Genesee and Niagara Rivers have been analyzed with the exception of pesticides and PCB's, which are being done by LOTEL. These data have been sent to EPA for input to the STORET system. The GLL plans to utilize the capacity of the latter computer system to plot and analyse these data.

4. Summary of Results

The analysis of sediment data from the Welland-Rochester Near-shore zone showed a definite influence from the Niagara River on the benthic chemistry (Figure 1-30).

The nature of the sediment downstream from the Niagara and Genesee Rivers was quite sandy especially at stations 208, 211, 243 and 245. The percent volatile solids were highest at the 4 and 8 km stations near the Niagara River plume (stations 205, 206, 208 and 209) and decrease steadily moving east towards Rochester. Generally the percent dry weights decreased and the percent volatile solids

Figure 1

MEAN VALUES

PERCENT DRY WEIGHTS
and
PERCENT VOLATILE SOLIDS

NEAR-SHORE SEDIMENTS

1972 IFYGL
% Dry Weight(avg.)
% Volatile Solids(avg.)

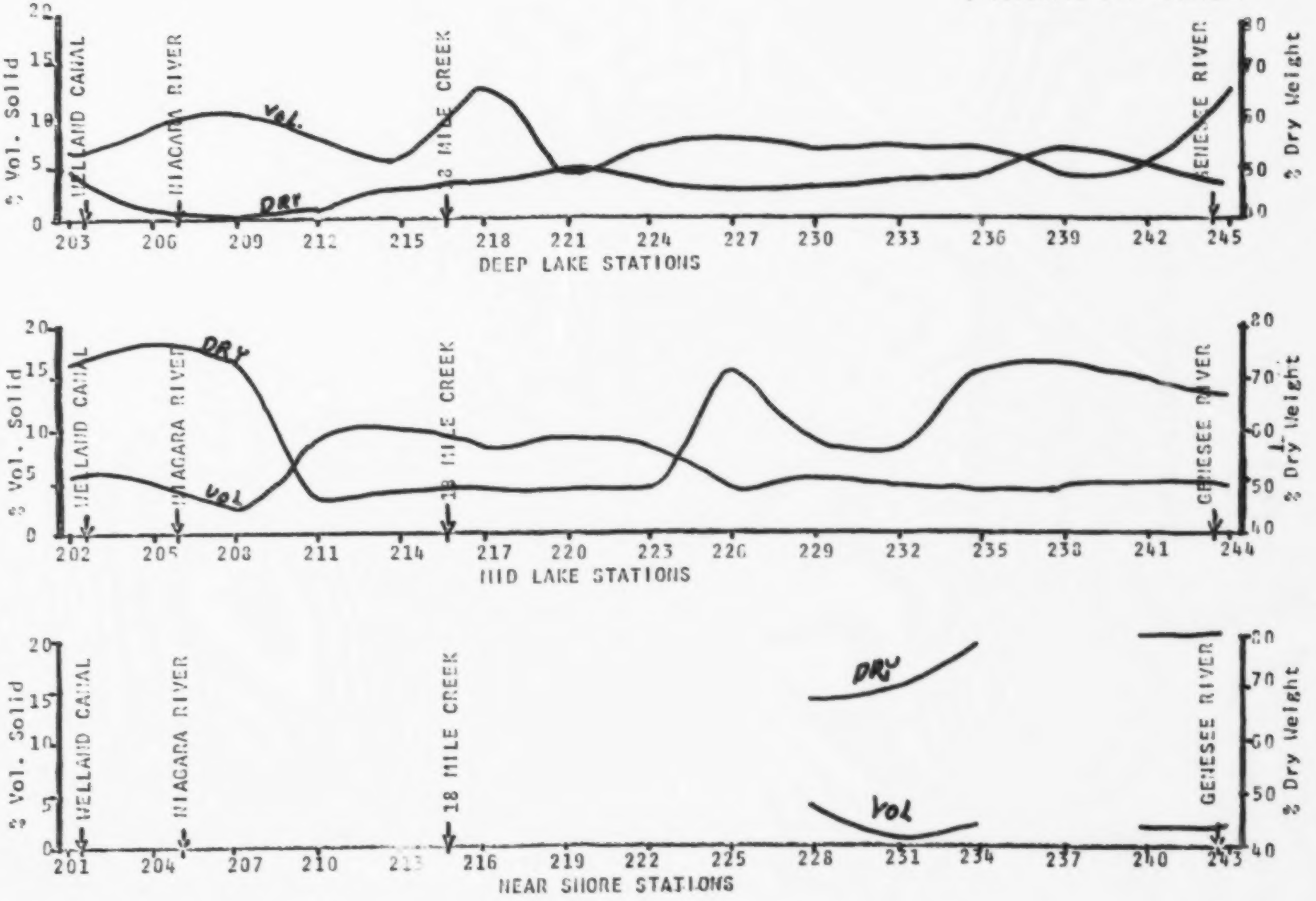


Figure 2

MEAN VALUES

NITRATE NITROGEN (mg/g)

and

ORGANIC NITROGEN (mg/g)

NEAR-SHORE SEDIMENTS

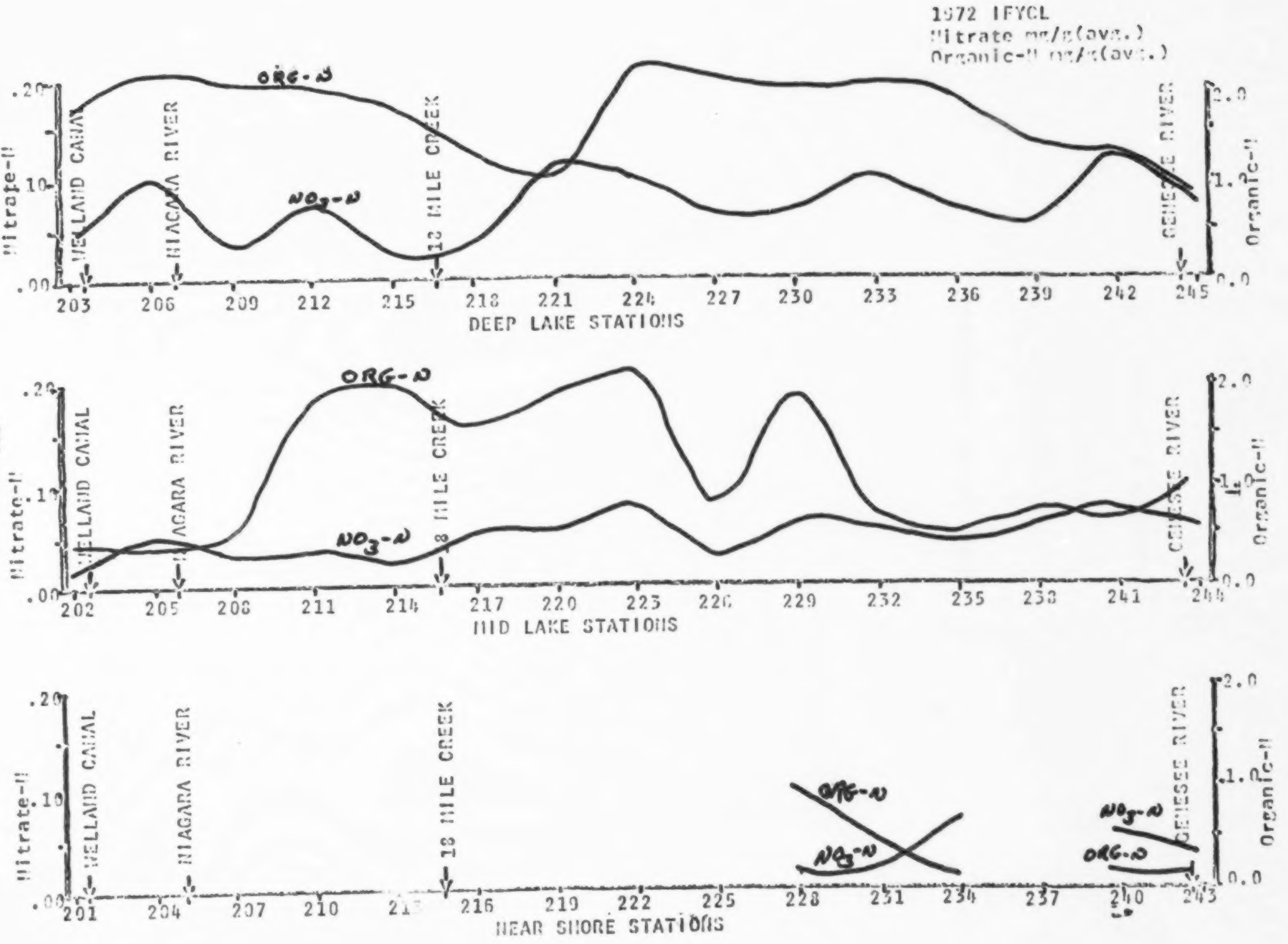

1972 IFYGL
Nitrate mg/l(avg.)
Organic-N mg/l(avg.)
ORG-N
NO3-N
Nitrate-N
Organic-N
.20
.10
.00
2.0
1.0
0.0
WELLAND CANAL
NIAGARA RIVER
18 MILE CREEK
GENESEE RIVER
203 206 209 212 215 218 221 224 227 230 233 236 239 242 245
DEEP LAKE STATIONS
202 205 208 211 214 217 220 223 226 229 232 235 238 241 244
MID LAKE STATIONS
201 204 207 210 213 216 219 222 225 228 231 234 237 240 243
NEAR SHORE STATIONS

Figure 3

MEAN VALUES

AMMONIA NITROGEN (mg/g)
and
TOTAL NITROGEN (mg/g)

NEAR-SHORE SEDIMENTS

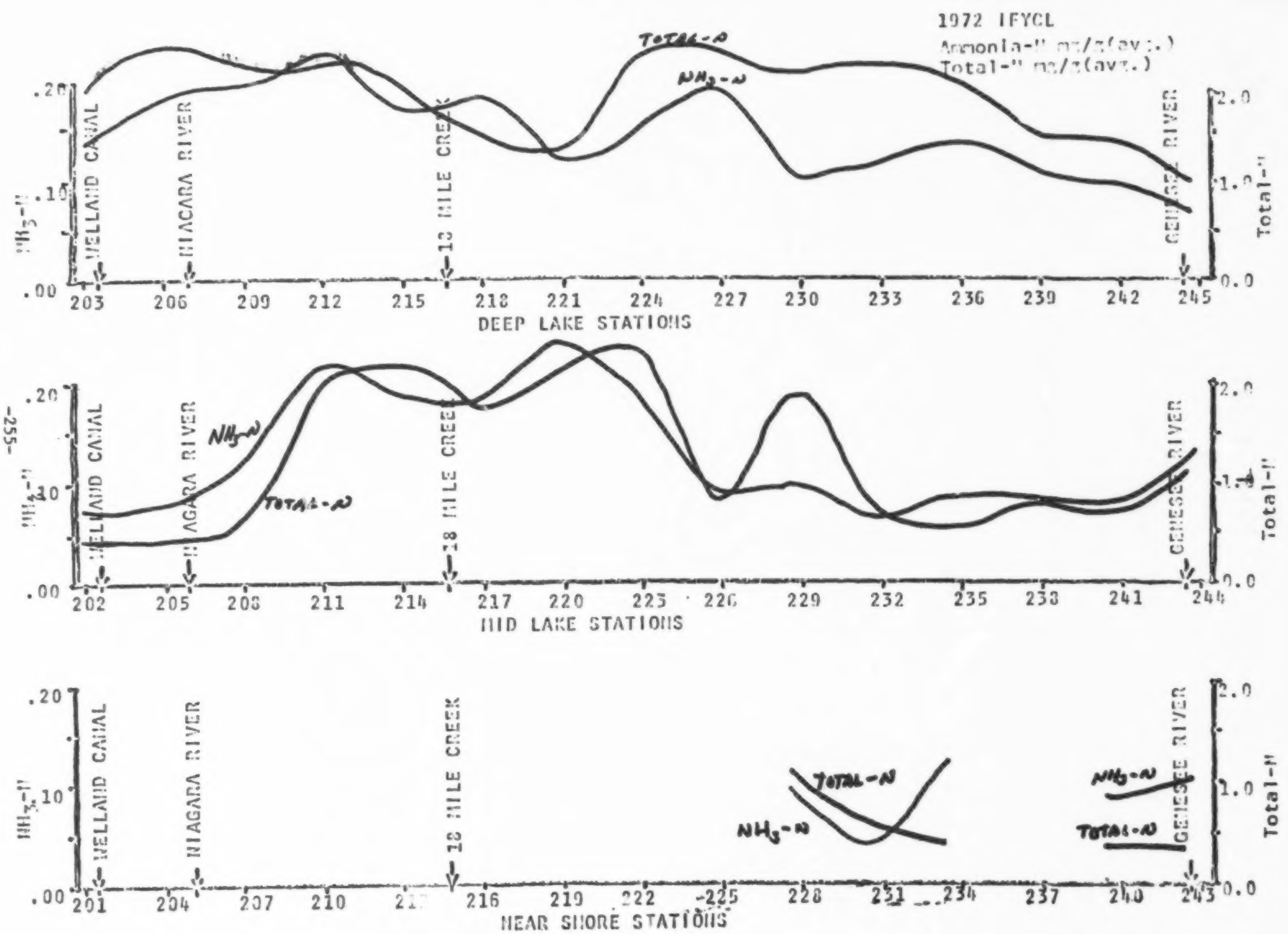

1972 IFYGL
Ammonia-N mg/l(avg.)
Total-N mg/l(avg.)
TOTAL-N
NH3-N
NH3-N
.20
.10
.00
Total-N
2.0
1.0
0.0
WELLAND CANAL
NIAGARA RIVER
18 MILE CREEK
GENESEE RIVER
203
206
209
212
215
218
221
224
227
230
233
236
239
242
245
DEEP LAKE STATIONS
NH3-N
TOTAL-N
202
205
208
211
214
217
220
223
226
229
232
235
238
241
244
MID LAKE STATIONS
TOTAL-N
NH3-N
NH3-N
TOTAL-N
201
204
207
210
213
216
219
222
225
228
231
234
237
240
243
NEAR SHORE STATIONS

Figure 4

MEAN VALUES

DISSOLVED PHOSPHORUS (mg/g)
and
TOTAL PHOSPHORUS (mg/g)

NEAR-SHORE SEDIMENTS

1972 IFYGL
DISSOLVED-P mg/g(avg.)
Total-P mg/g(avg.)

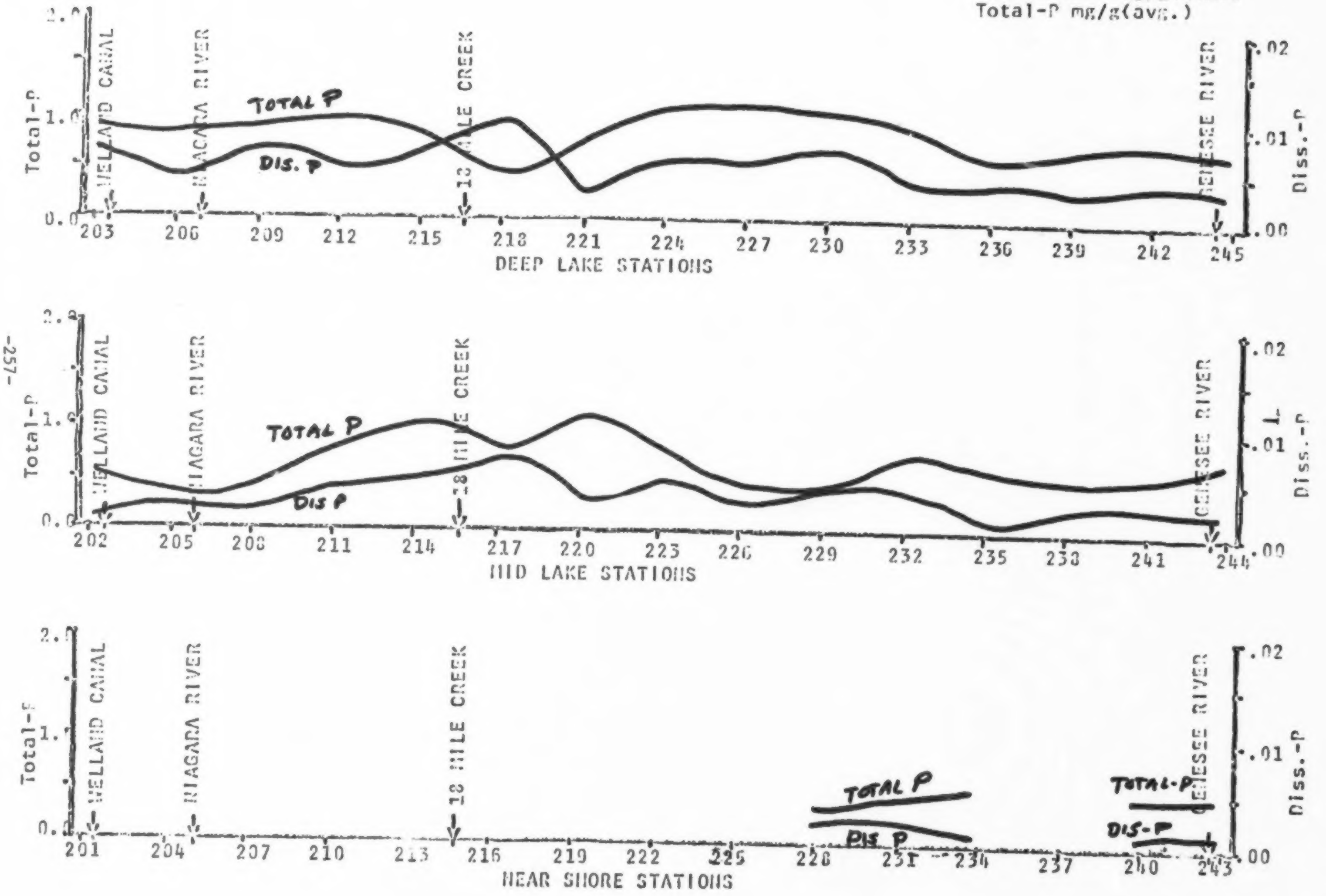


Figure 5

MEAN VALUES

PERCENT TOTAL ORGANIC CARBON
and
PERCENT TOTAL INORGANIC CARBON

NEAR-SHORE SEDIMENTS

1972 IFYGL
%T.O.C.(avg.)
%T.I.C.(avg.)

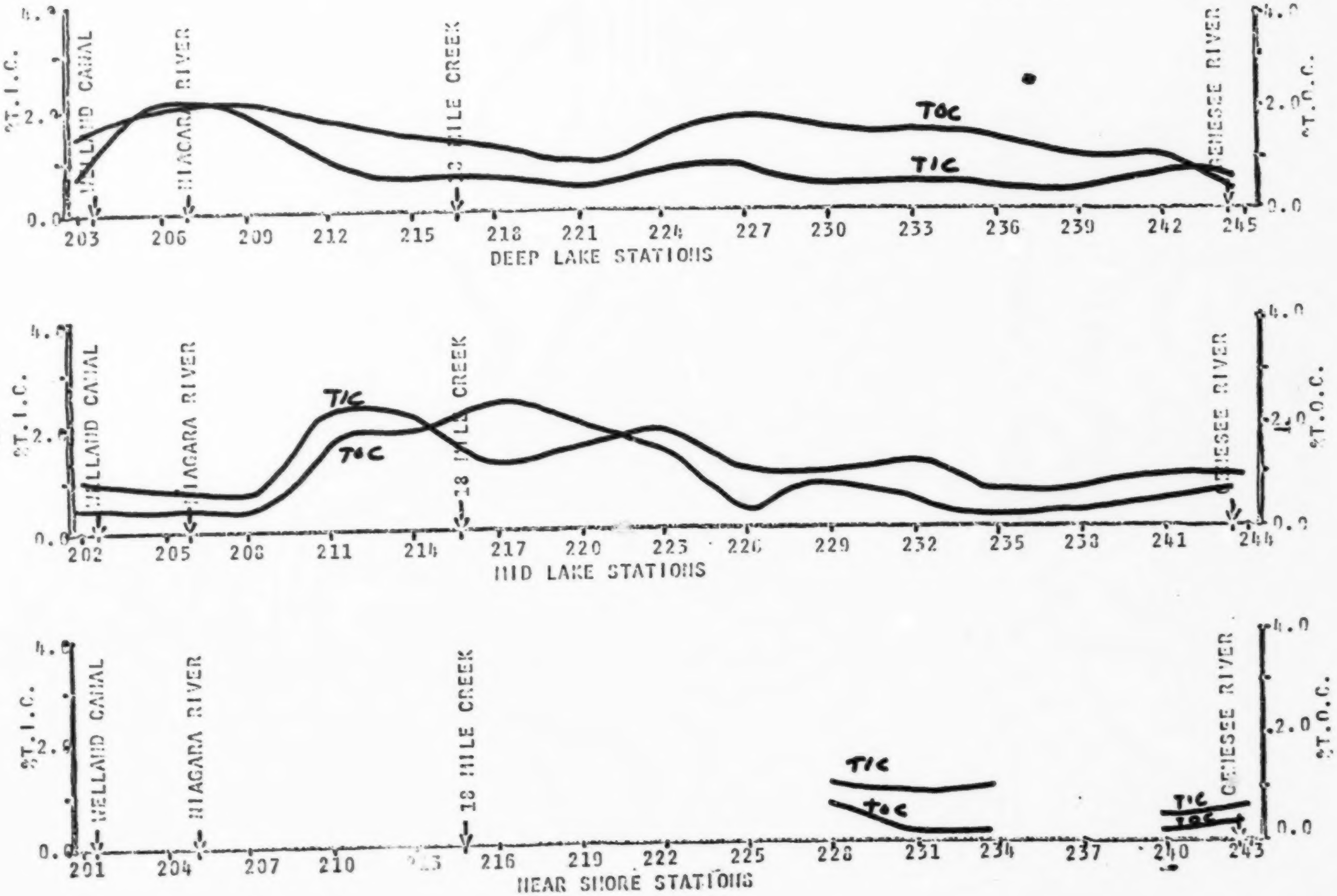


Figure 6

MEAN VALUES

IRON (μg/g)

and

MAGNESIUM (μg/g)

NEAR-SHORE SEDIMENTS

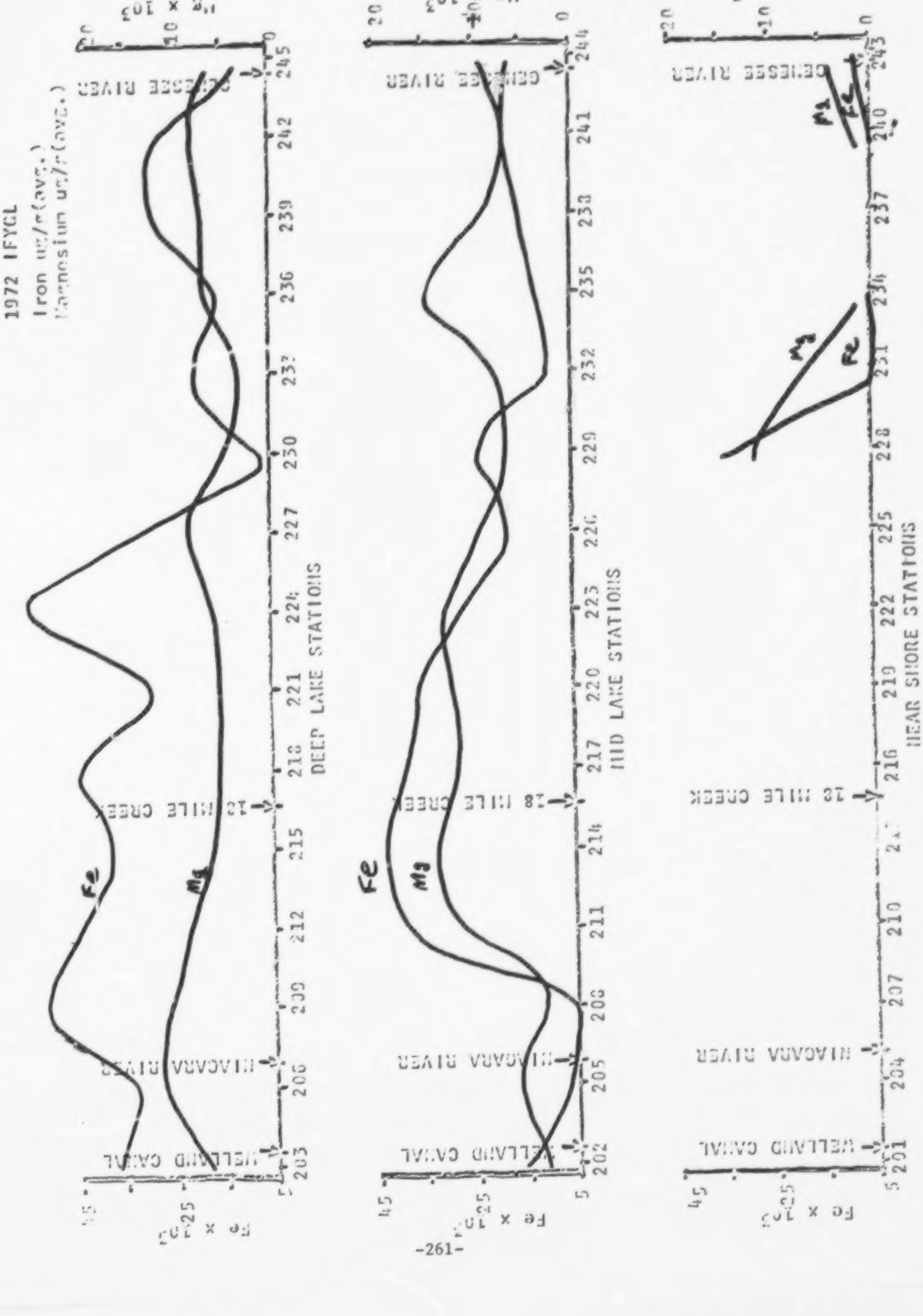

1972 IFYGL
Iron ug/l (avg.)
Magnesium ug/l (avg.)
Mg x 10³
Fe x 10³
DEEP LAKE STATIONS
MID LAKE STATIONS
NEAR SHORE STATIONS
WELLAND CANAL
NIAGARA RIVER
18 MILE CREEK
GENESSE RIVER
Fe
Mg
203
206
209
212
215
218
221
224
227
230
233
236
239
242
245
202
205
208
211
214
217
220
223
226
229
232
235
238
241
244
201
204
207
210
213
216
219
222
225
228
231
234
237
240
243
0
10
20
5
25
45

Figure 7

MEAN VALUES

MANGANESE (µg/g)

and

ZINC (µg/g)

NEAR-SHORE SEDIMENTS

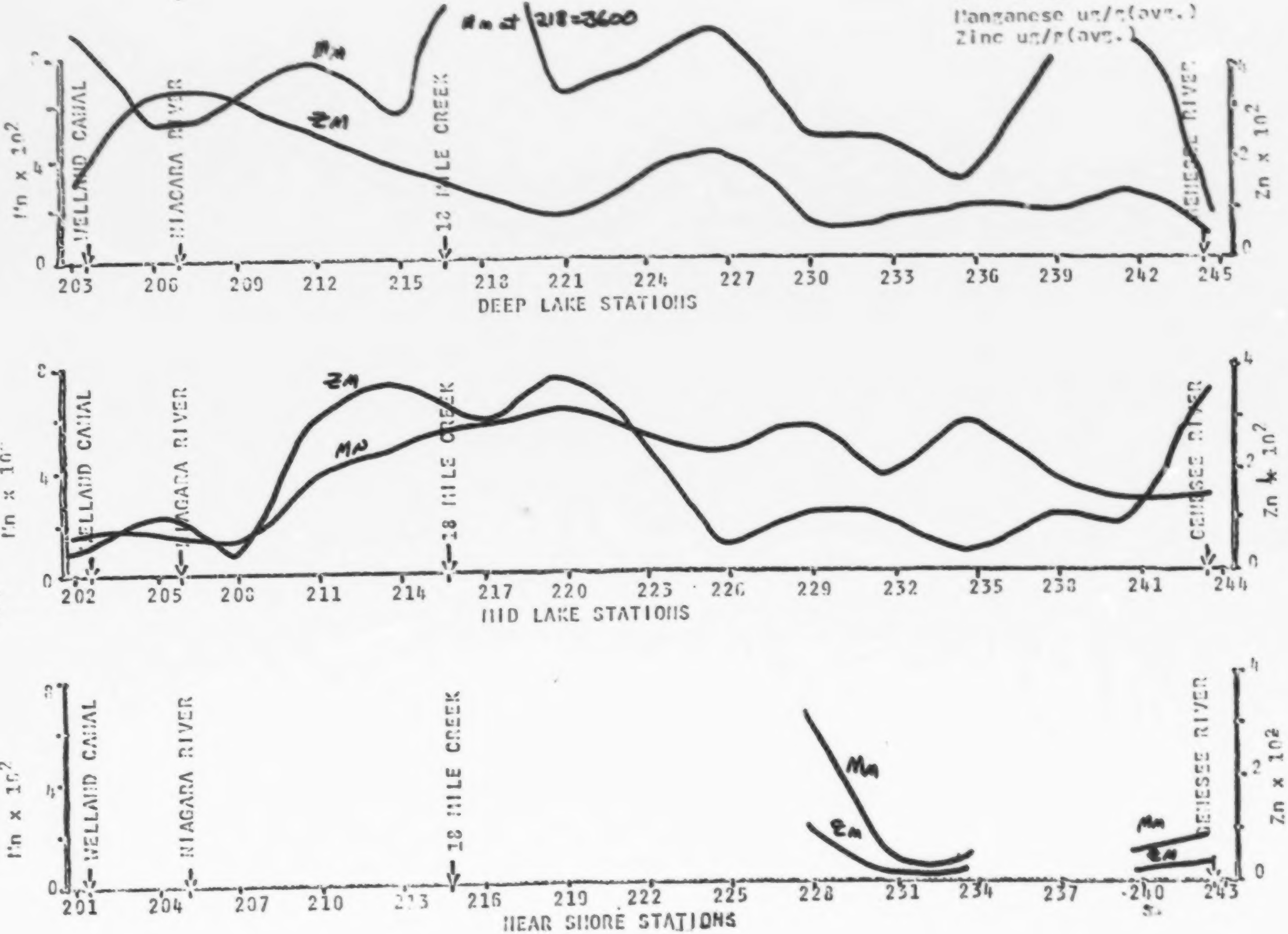

1972 IFYGL
Manganese ug/g(avg.)
Zinc ug/g(avg.)
Mn at 218=3600
Mn
Zn
Mn x 10²
Zn x 10²
0
4
8
2
WELLAND CANAL
NIAGARA RIVER
12 MILE CREEK
GENESEE RIVER
203
206
209
212
215
218
221
224
227
230
233
236
239
242
245
DEEP LAKE STATIONS
18 MILE CREEK
202
205
208
211
214
217
220
223
226
229
232
235
238
241
244
MID LAKE STATIONS
201
204
207
210
213
216
219
222
225
228
231
234
237
240
243
NEAR SHORE STATIONS

Figure 8

MEAN VALUES

COPPER (μg/g)

and

LEAD (μg/g)

NEAR-SHORE SEDIMENTS

1972 IFYGL
Copper ug/g(avg.)
Lead ug/g(avg.)

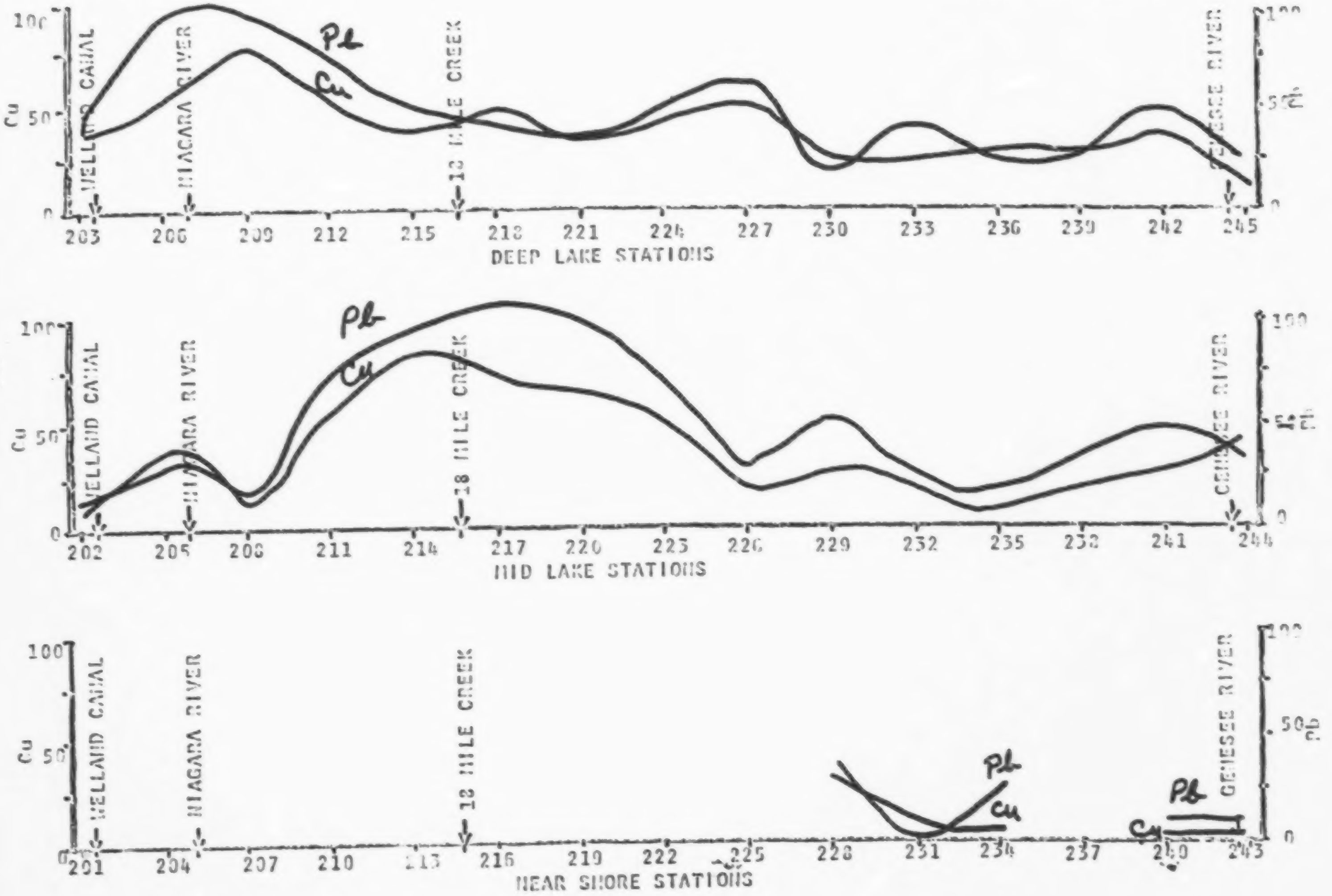


Figure 9

MEAN VALUES

CADMIUM (µg/g)

and

CHROMIUM (µg/g)

NEAR-SHORE SEDIMENTS

1972 IFYGL
Cadmium ug/g(avg.)
Chromium ug/g(avg.)

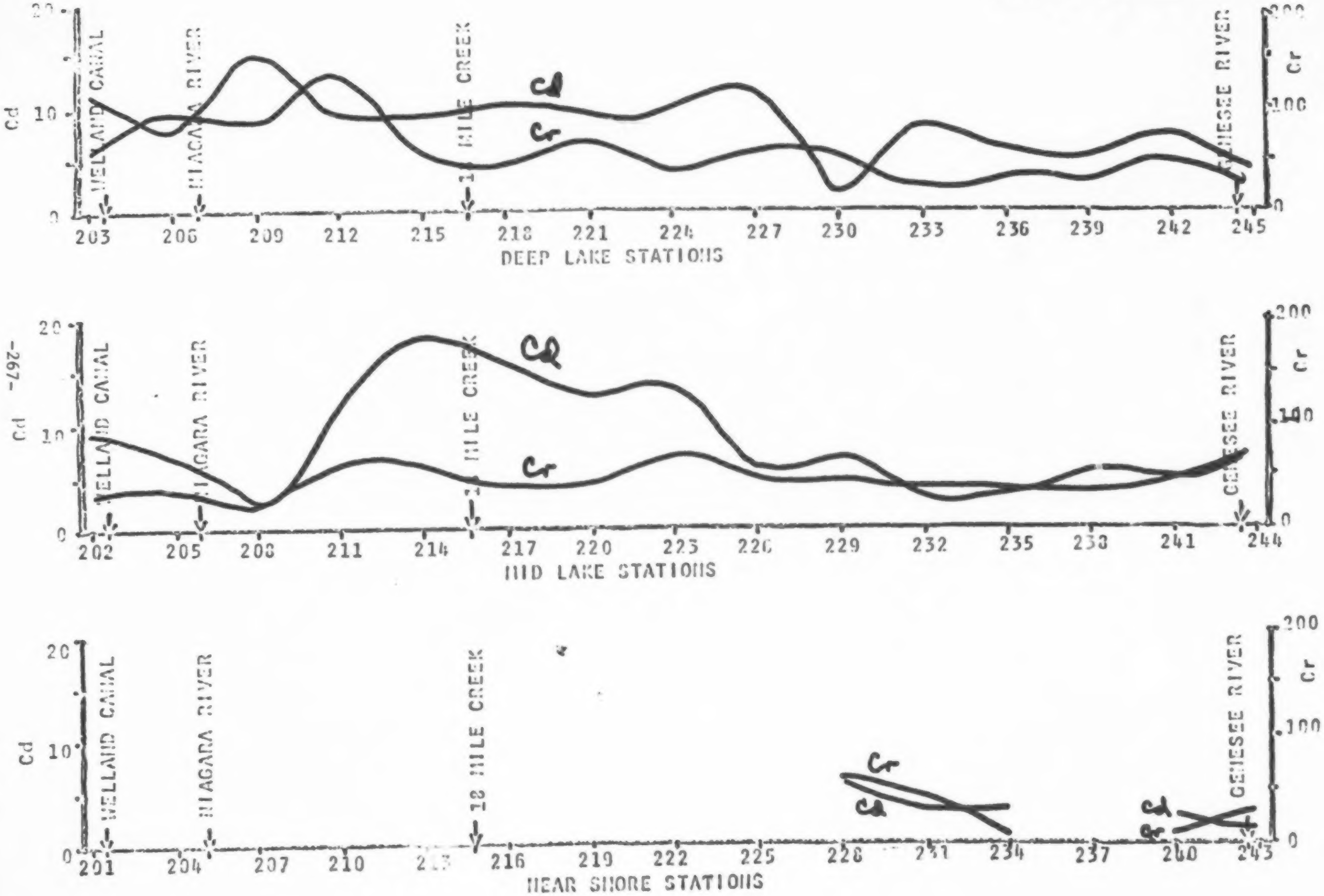
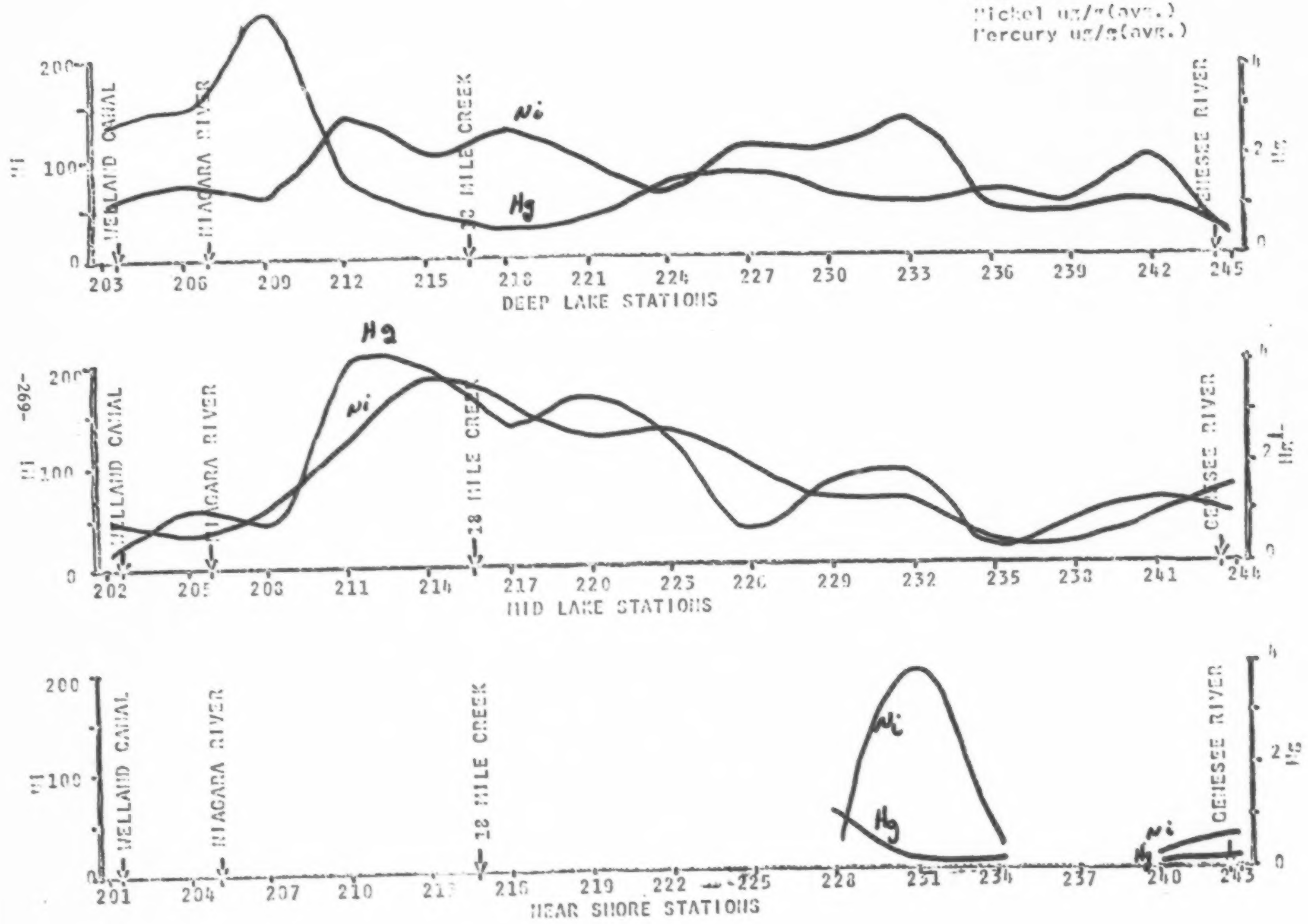


Figure 10

MEAN VALUES

NICKEL (µg/g)
and
MERCURY (µg/g)

NEAR-SHORE SEDIMENTS



1972 IFYGL
Nickel ug/g(avg.)
Mercury ug/g(avg.)

Figure 11

MEAN VALUES

PERCENT DRY WEIGHTS
and
PERCENT VOLATILE SOLIDS

GENESEE SEDIMENTS

1972 LEVEL

TRANSECT & LAKE

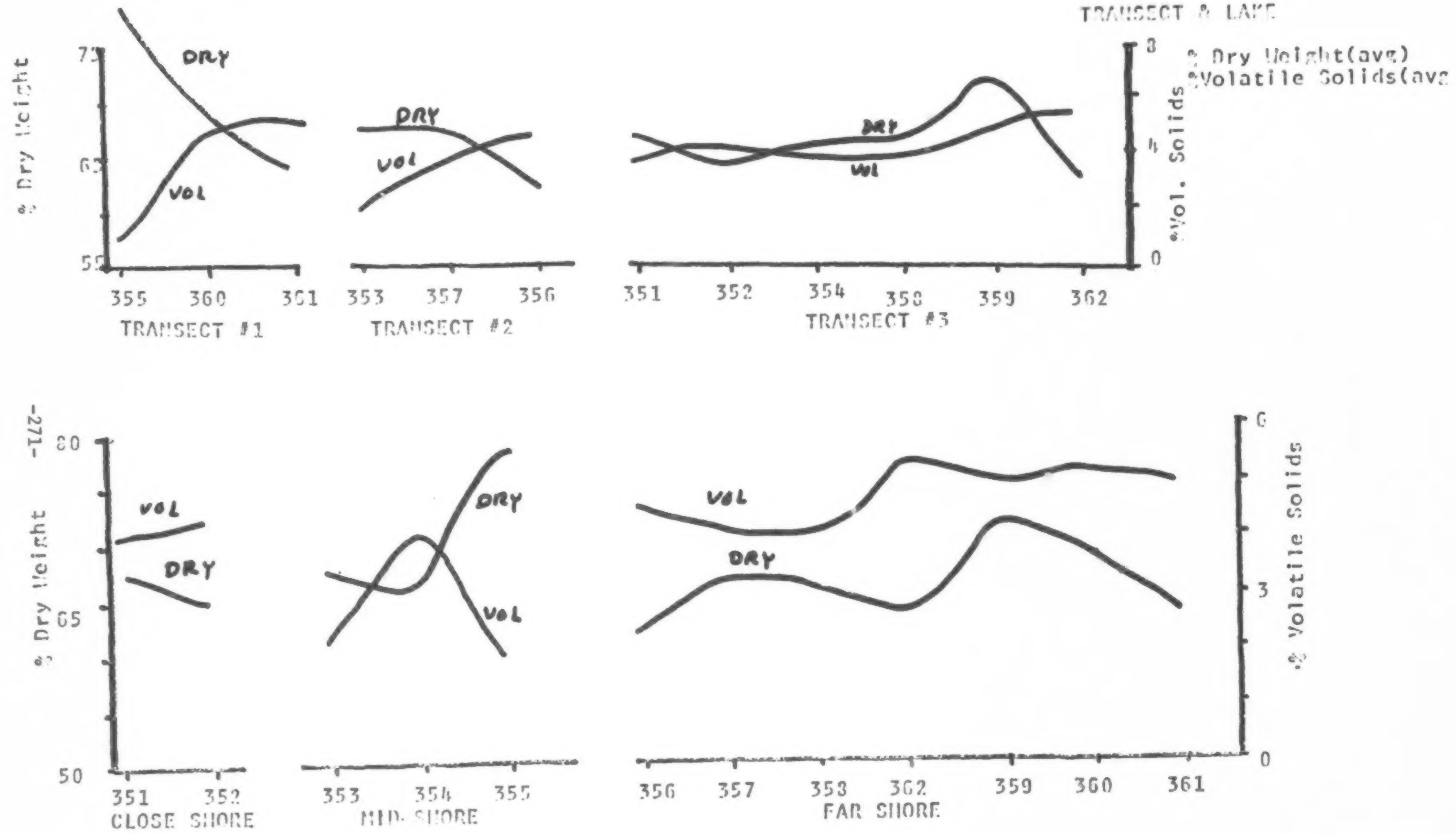


Figure 12

MEAN VALUES

NITRATE NITROGEN (mg/g)

and

ORGANIC NITROGEN (mg/g)

GENESEE SEDIMENT

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

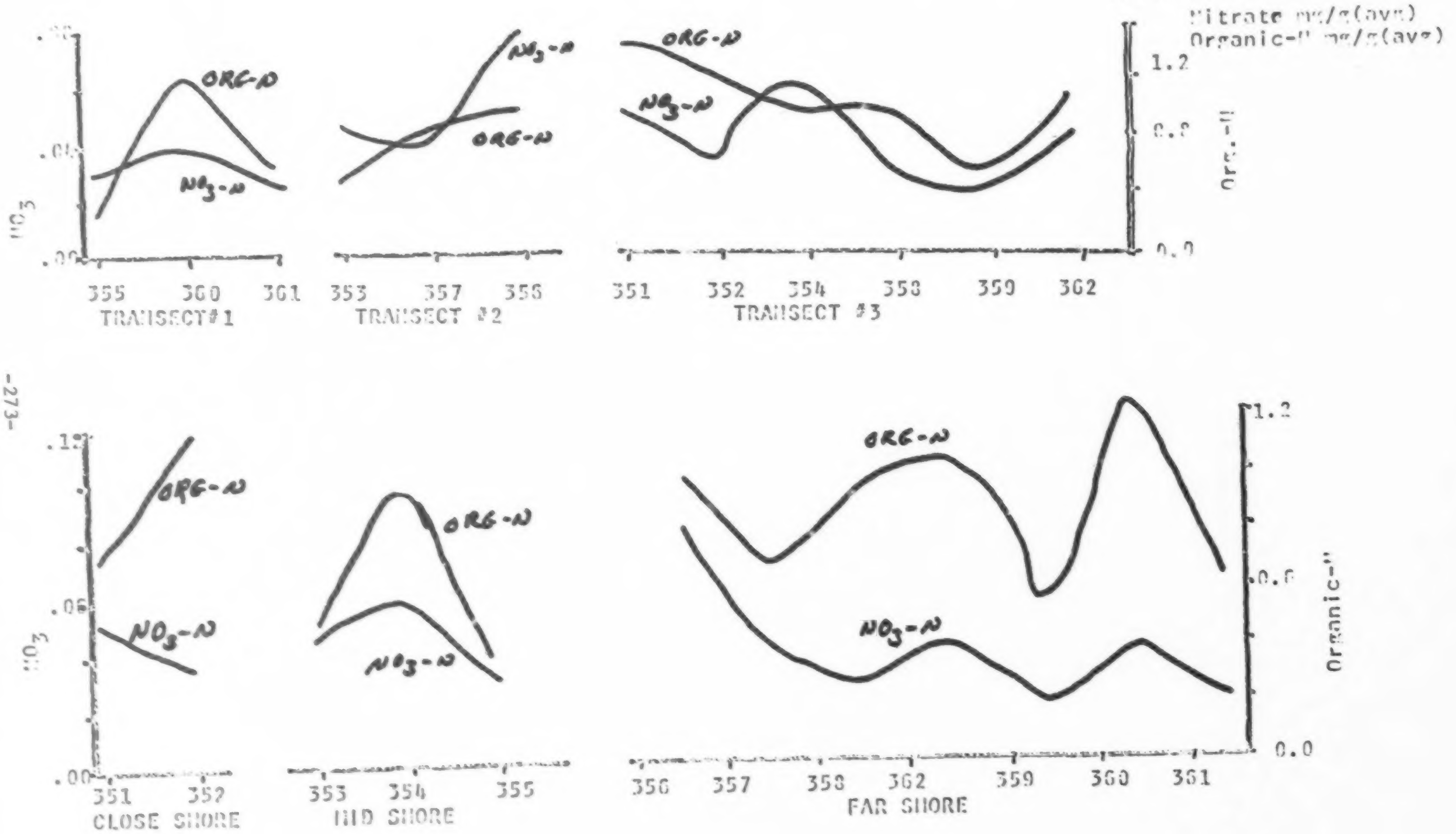


Figure 13

MEAN VALUES

AMMONIA NITROGEN (mg/g)

and

TOTAL NITROGEN (mg/g)

GENESEE SEDIMENTS

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

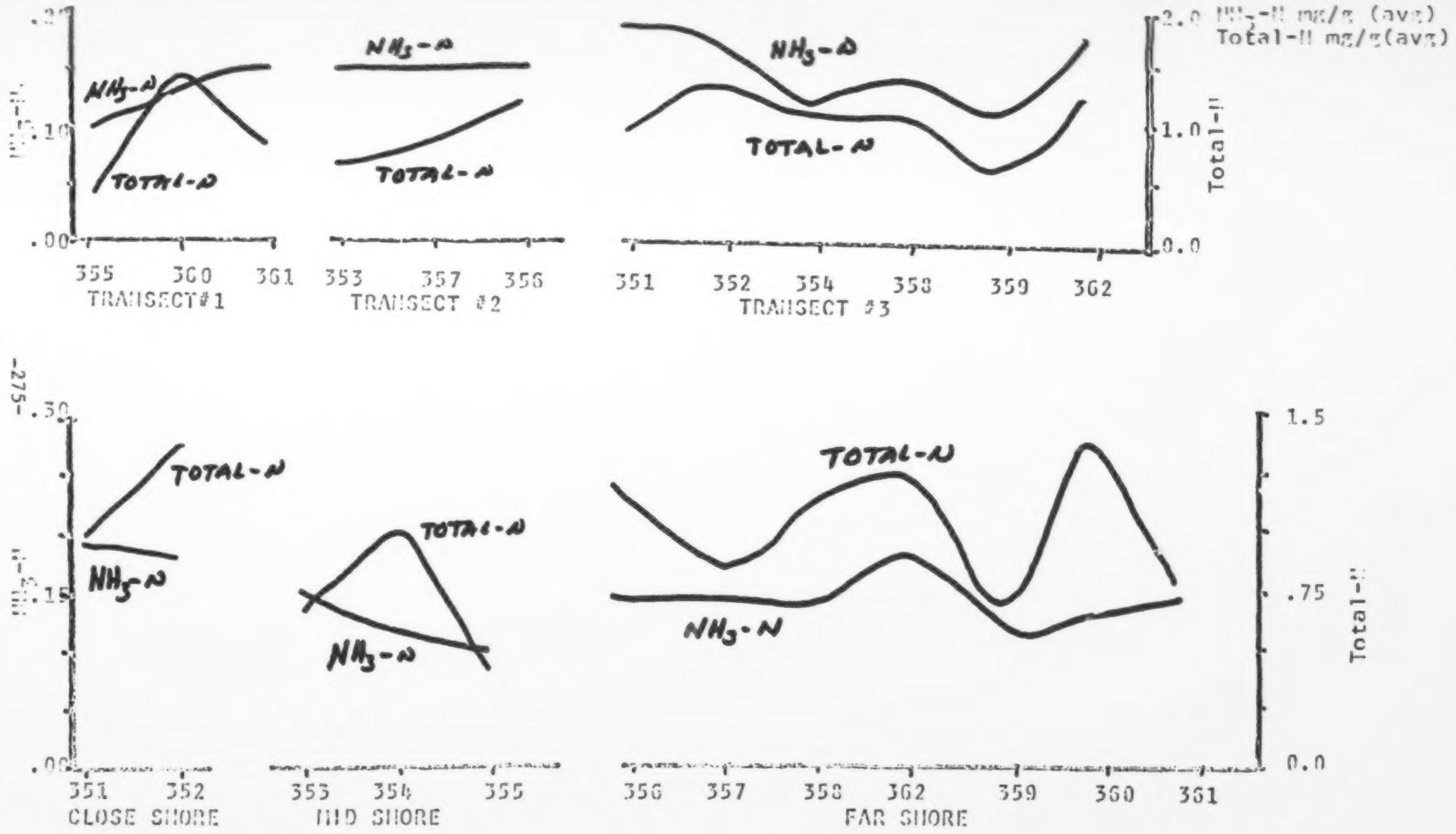


Figure 14

MEAN VALUES

DISSOLVED PHOSPHORUS (mg/g)

and

TOTAL PHOSPHORUS (mg/g)

GENESEE SEDIMENTS

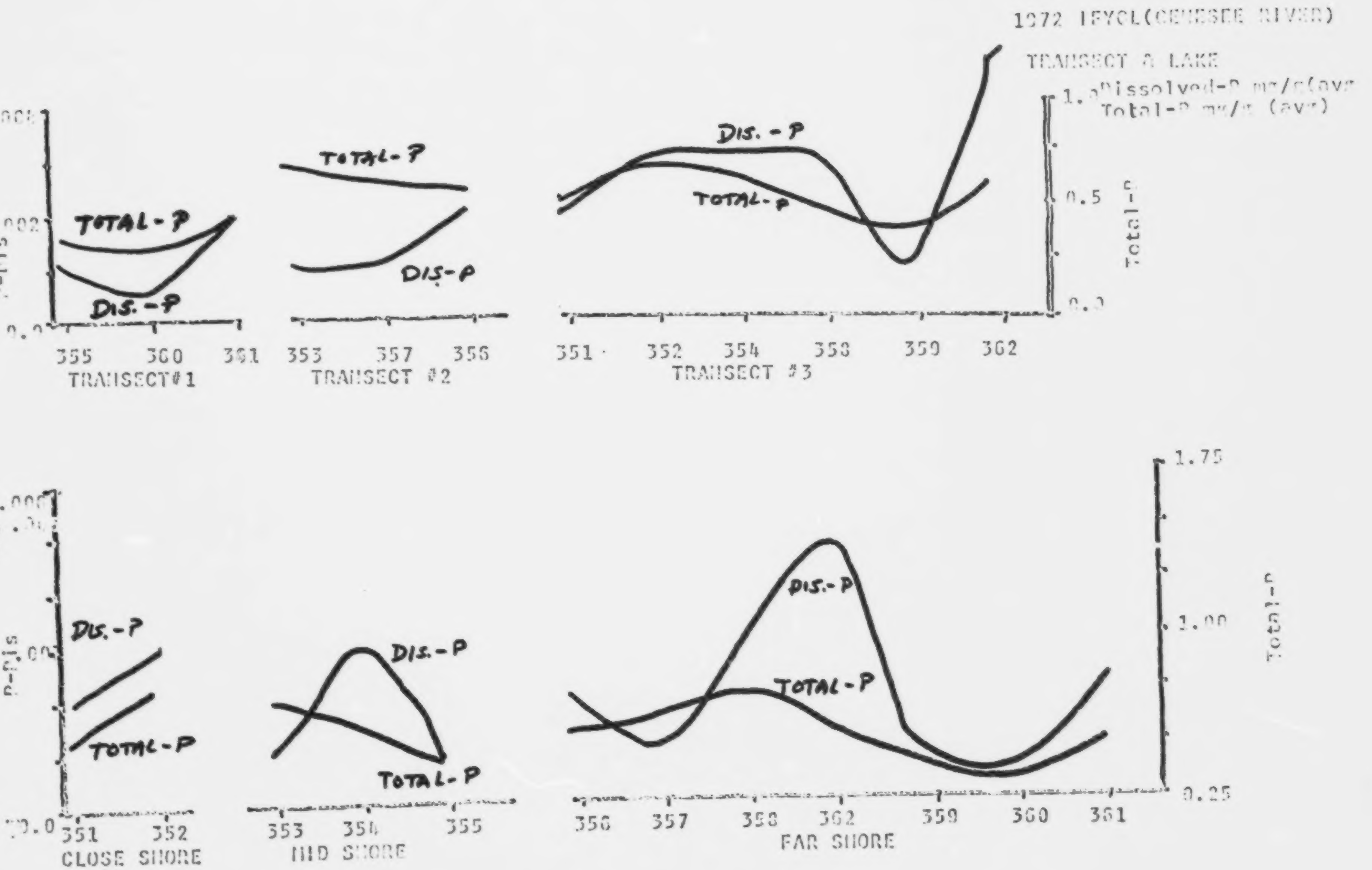

1972 IFYGL(GENESEE RIVER)
TRANSECT & LAKE
Dissolved-P mg/l(avg
Total-P mg/l (avg)
P-Dis
.008
.002
0.0
TOTAL-P
DIS.-P
355
360
361
TRANSECT#1
TOTAL-P
DIS-P
353
357
356
TRANSECT #2
DIS.-P
TOTAL-P
351
352
354
358
359
362
TRANSECT #3
Total-P
1.0
0.5
0.0
P-Dis
.008
.00
0.0
DIS.-P
TOTAL-P
351
352
CLOSE SHORE
DIS.-P
TOTAL-P
353
354
355
MID SHORE
DIS.-P
TOTAL-P
356
357
358
362
359
360
361
FAR SHORE
Total-P
1.75
1.00
0.25

Figure 15

MEAN VALUES

PERCENT TOTAL ORGANIC CARBON

and

PERCENT TOTAL INORGANIC CARBON

GENESEE SEDIMENTS

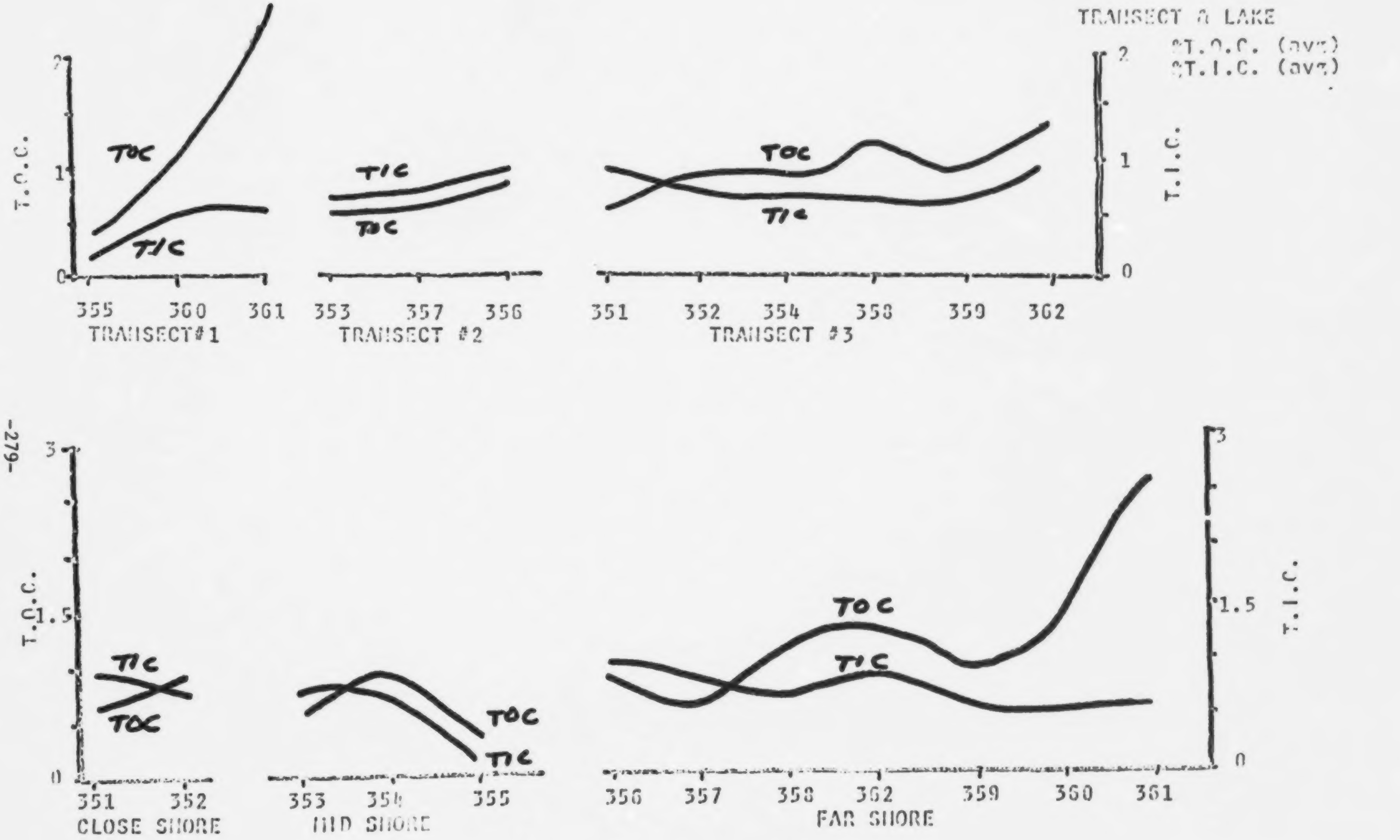


Figure 16

MEAN VALUES

IRON (µg/g)

and

MAGNESIUM (µg/g)

GENESEE SEDIMENTS

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

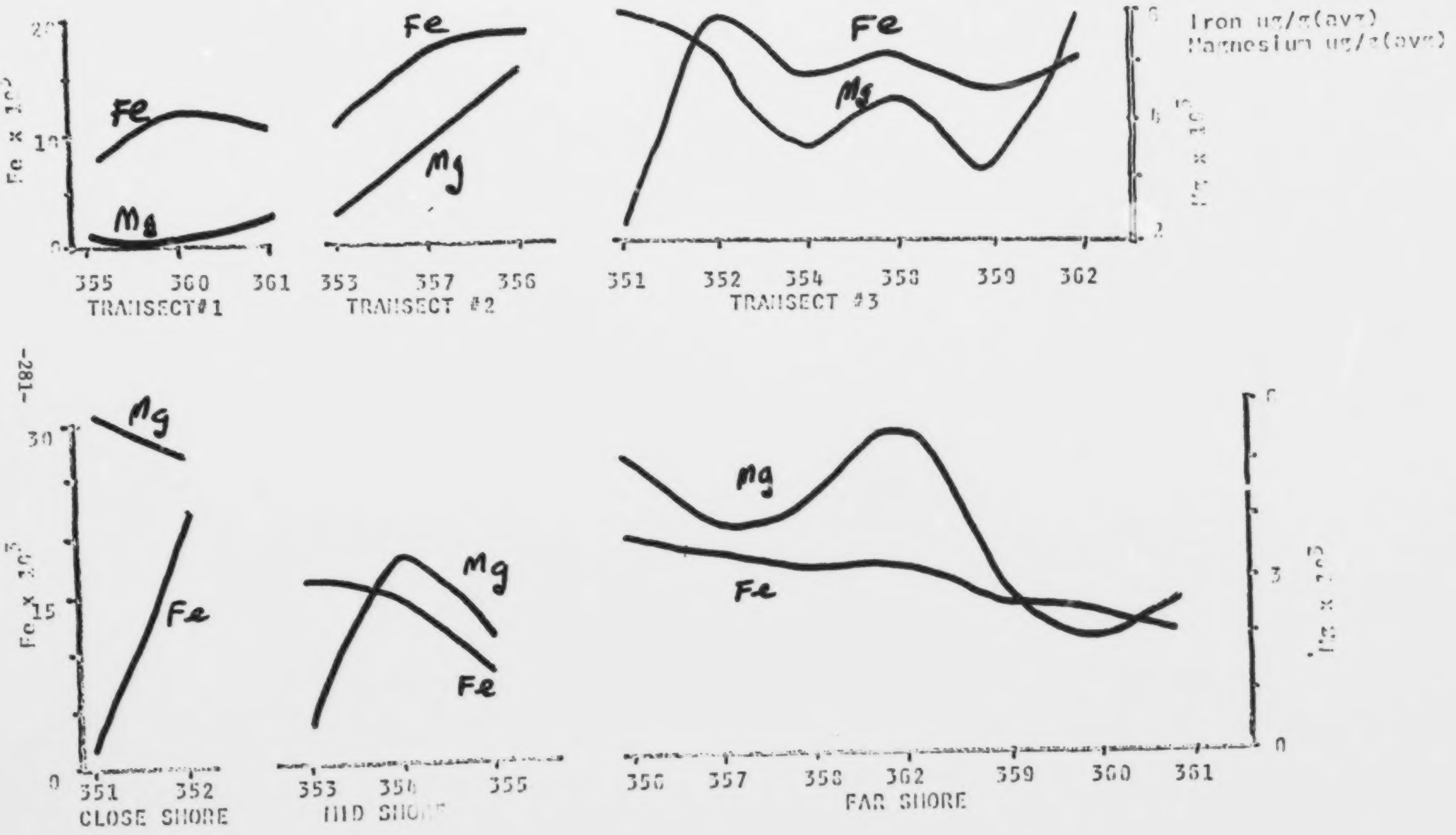


Figure 17

MEAN VALUES

MANGANESE (μg/g)

and

ZINC (μg/g)

GENESEE SEDIMENTS

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

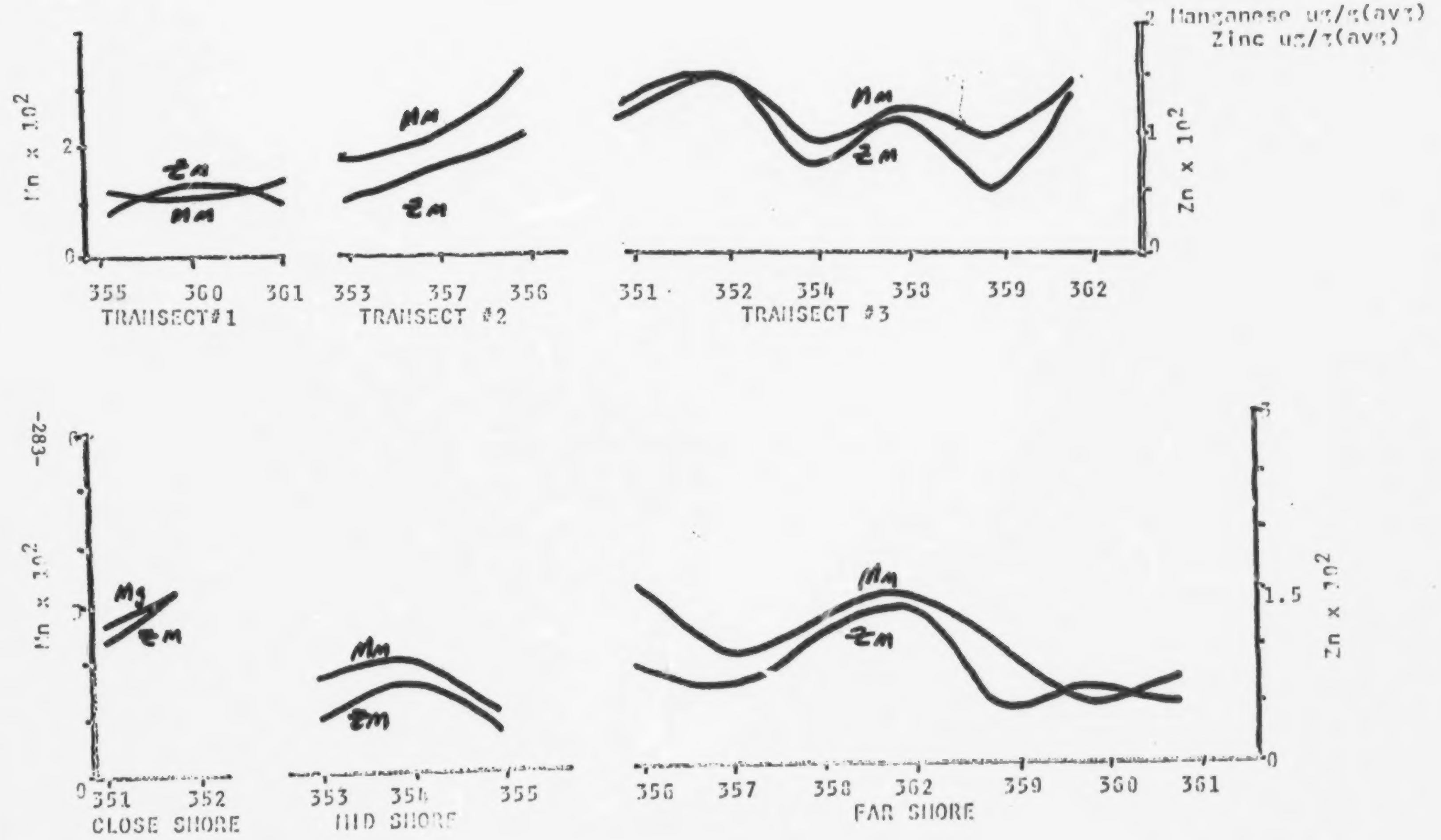


Figure 18

MEAN VALUES

COPPER (μg/g)

and

LEAD (μg/g)

GENESEE SEDIMENTS

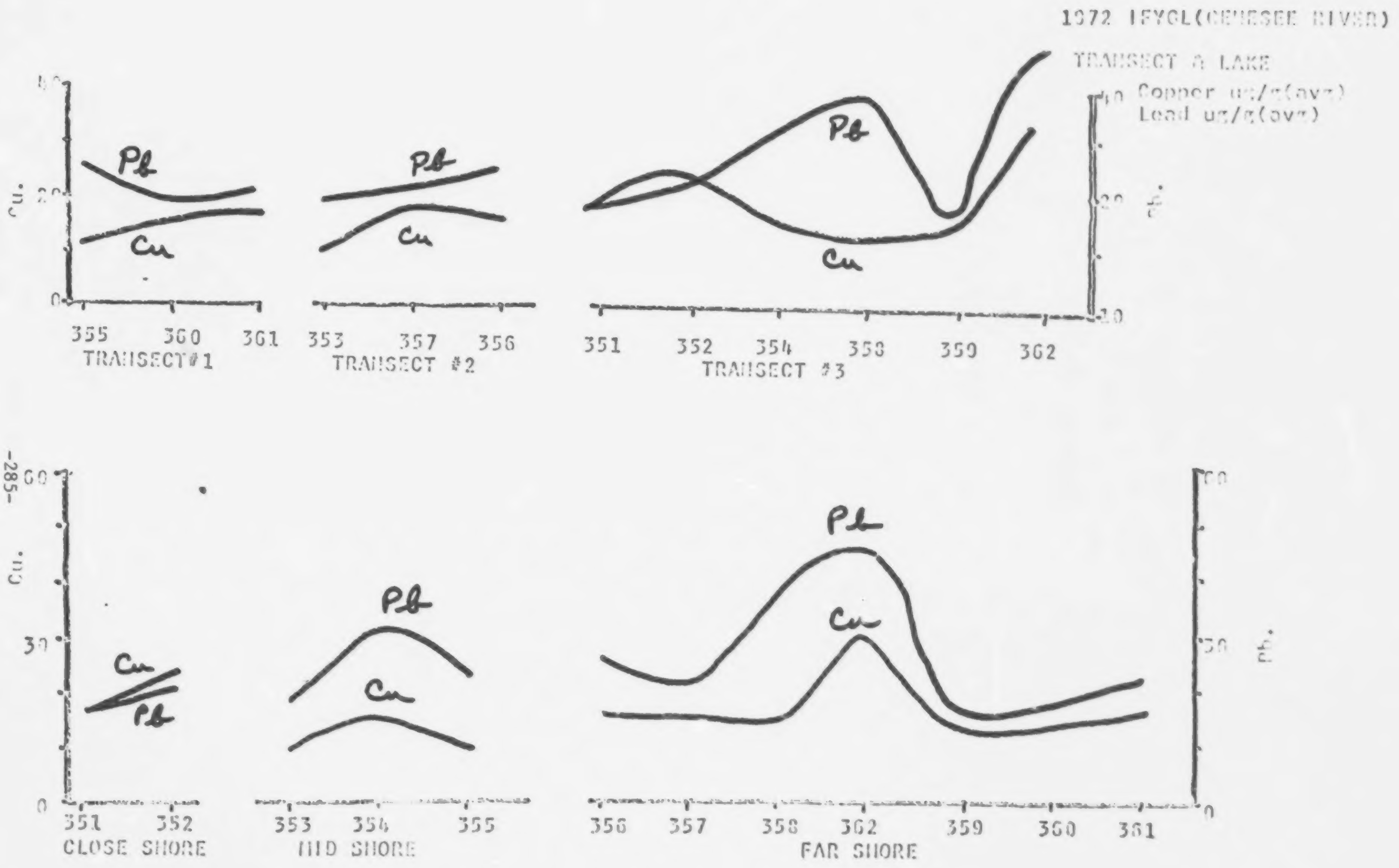

1972 IFYGL(GENESEE RIVER)
TRANSECT & LAKE
Copper ug/g(avg)
Lead ug/g(avg)
Cu.
Pb.
40
20
0
Pb
Cu
355
360
361
TRANSECT#1
353
357
356
TRANSECT #2
351
352
354
358
359
362
TRANSECT #3
60
30
0
351
352
CLOSE SHORE
353
354
355
MID SHORE
356
357
358
362
359
360
361
FAR SHORE

Figure 19

MEAN VALUES

CADMIUM (µg/g)

and

CHROMIUM (µg/g)

GENESEE SEDIMENTS

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

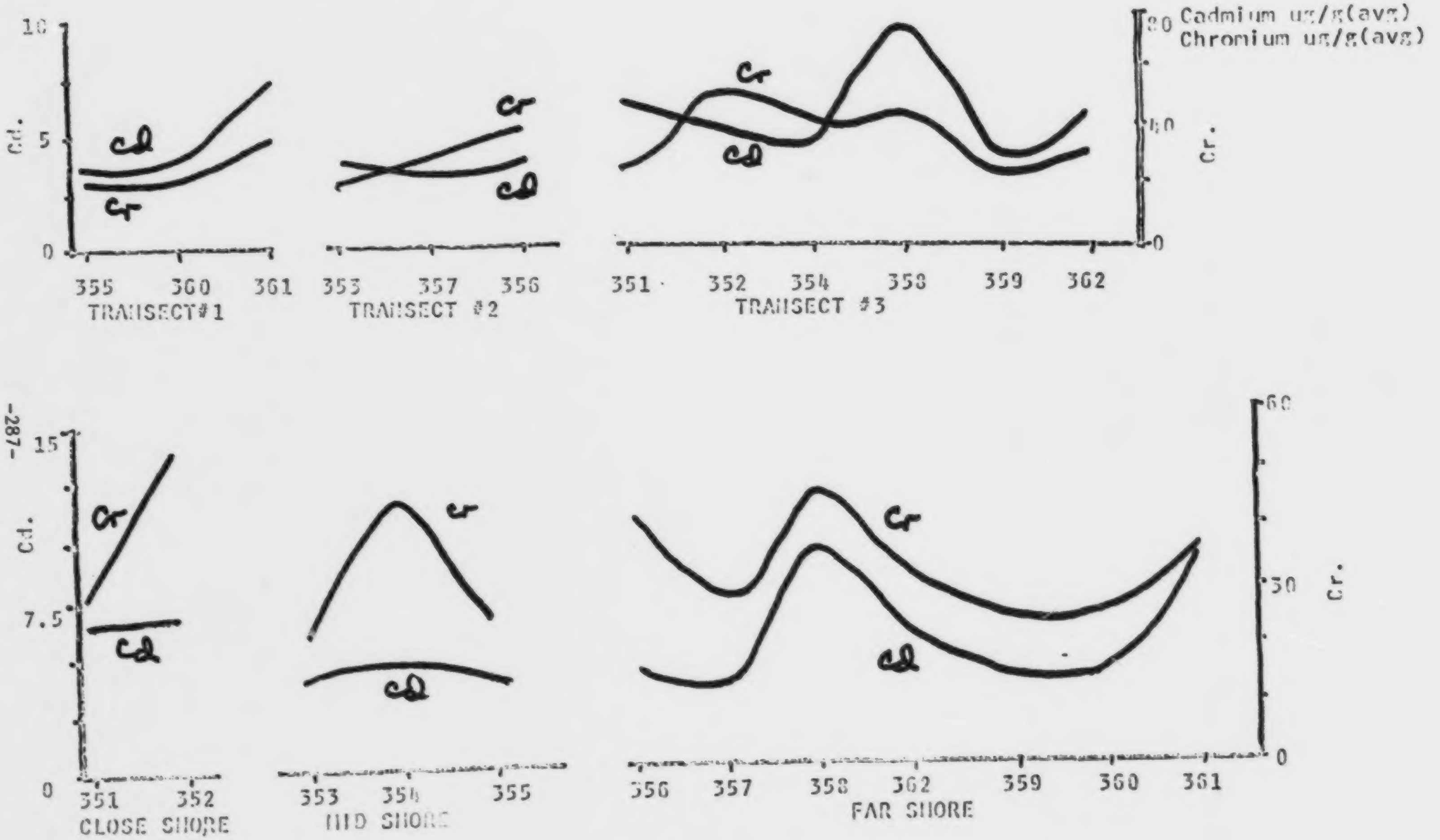


Figure 20

MEAN VALUES

NICKEL (µg/g)

and

MERCURY (µg/g)

GENESEE SEDIMENTS

1972 IFYGL(GENESEE RIVER)

TRANSECT & LAKE

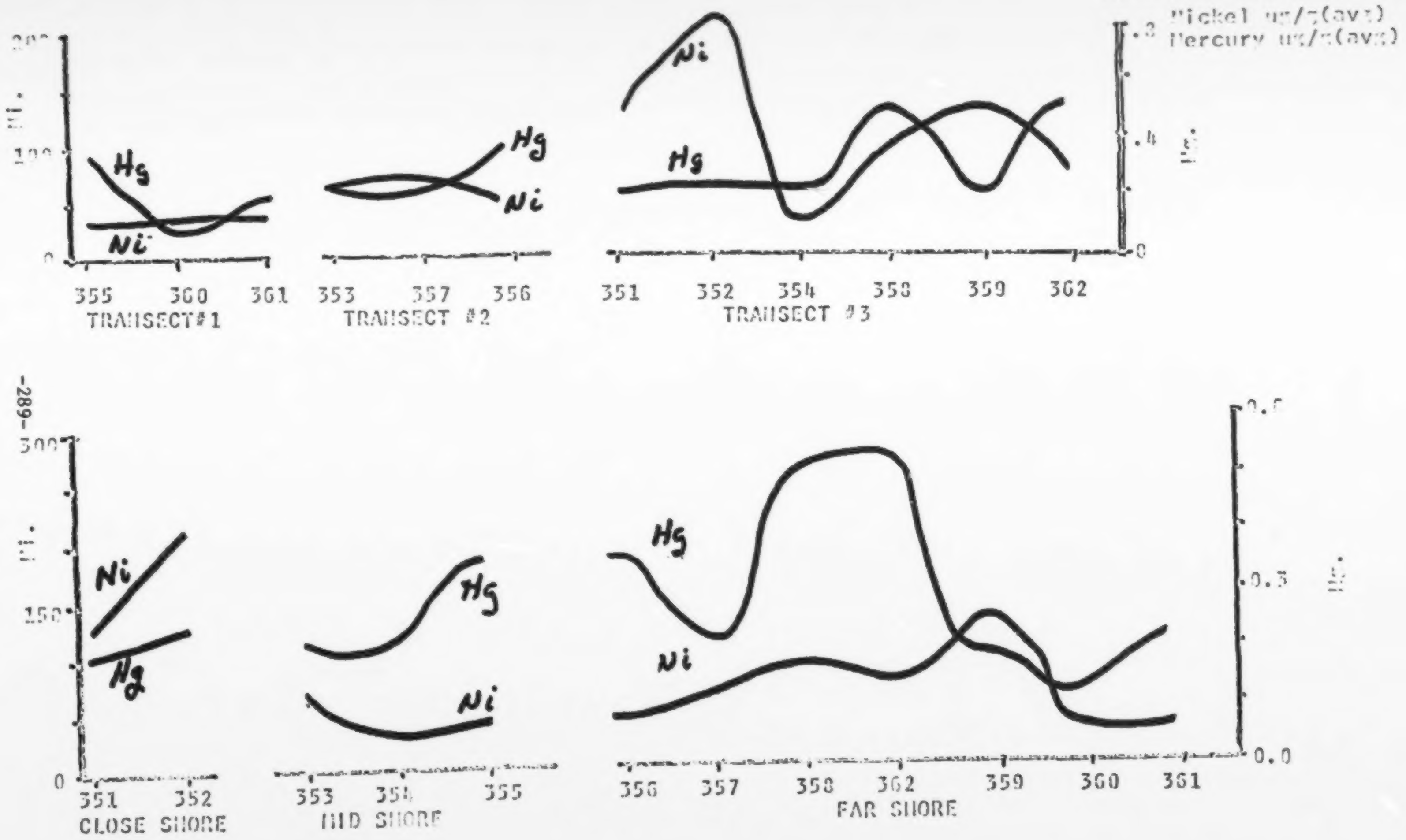


Figure 21

MEAN VALUES

PERCENT DRY WEIGHT

and

PERCENT VOLATILE WEIGHT

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE

Dry Weight & % Volatile Solids(avg)

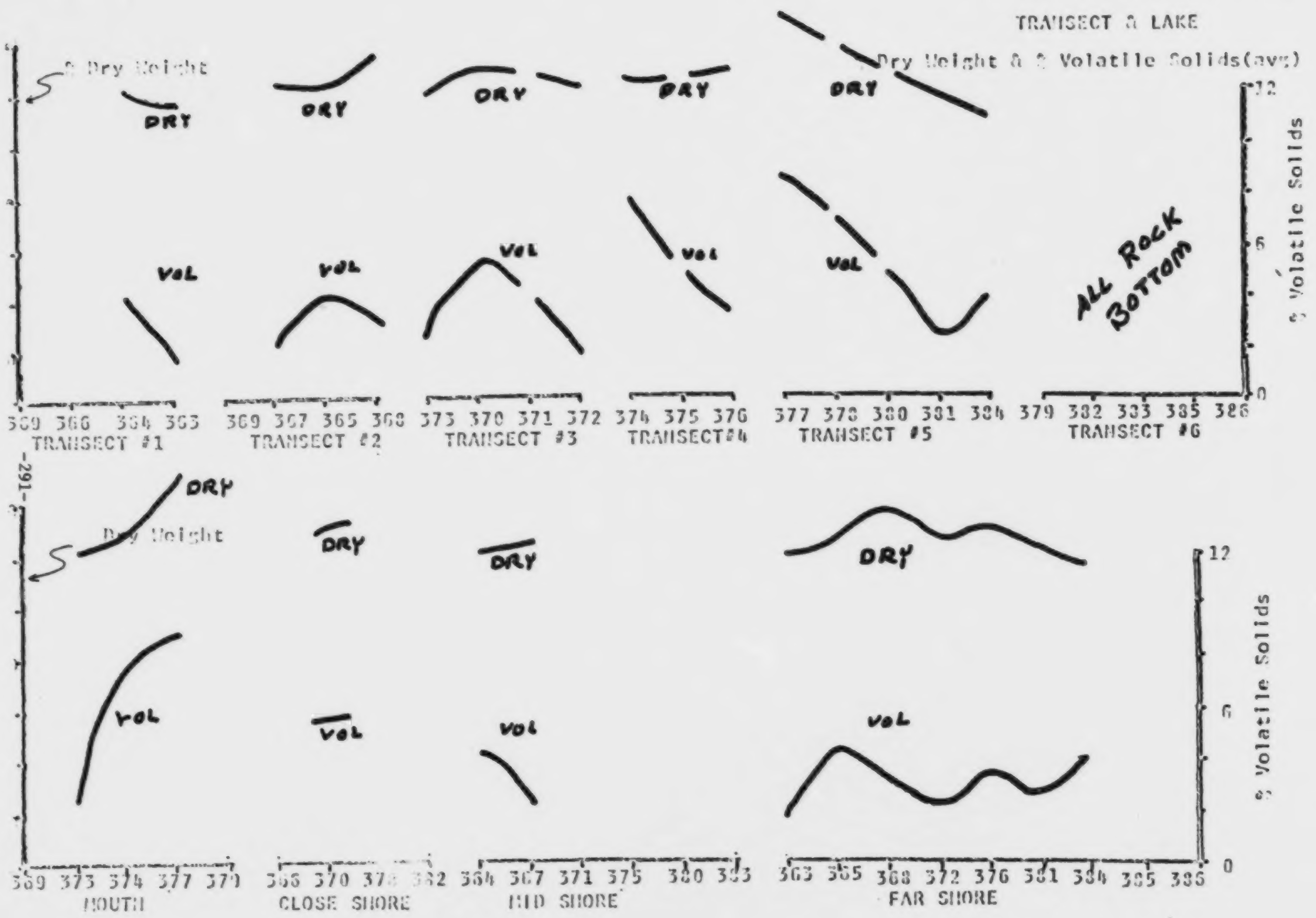


Figure 22

MEAN VALUES

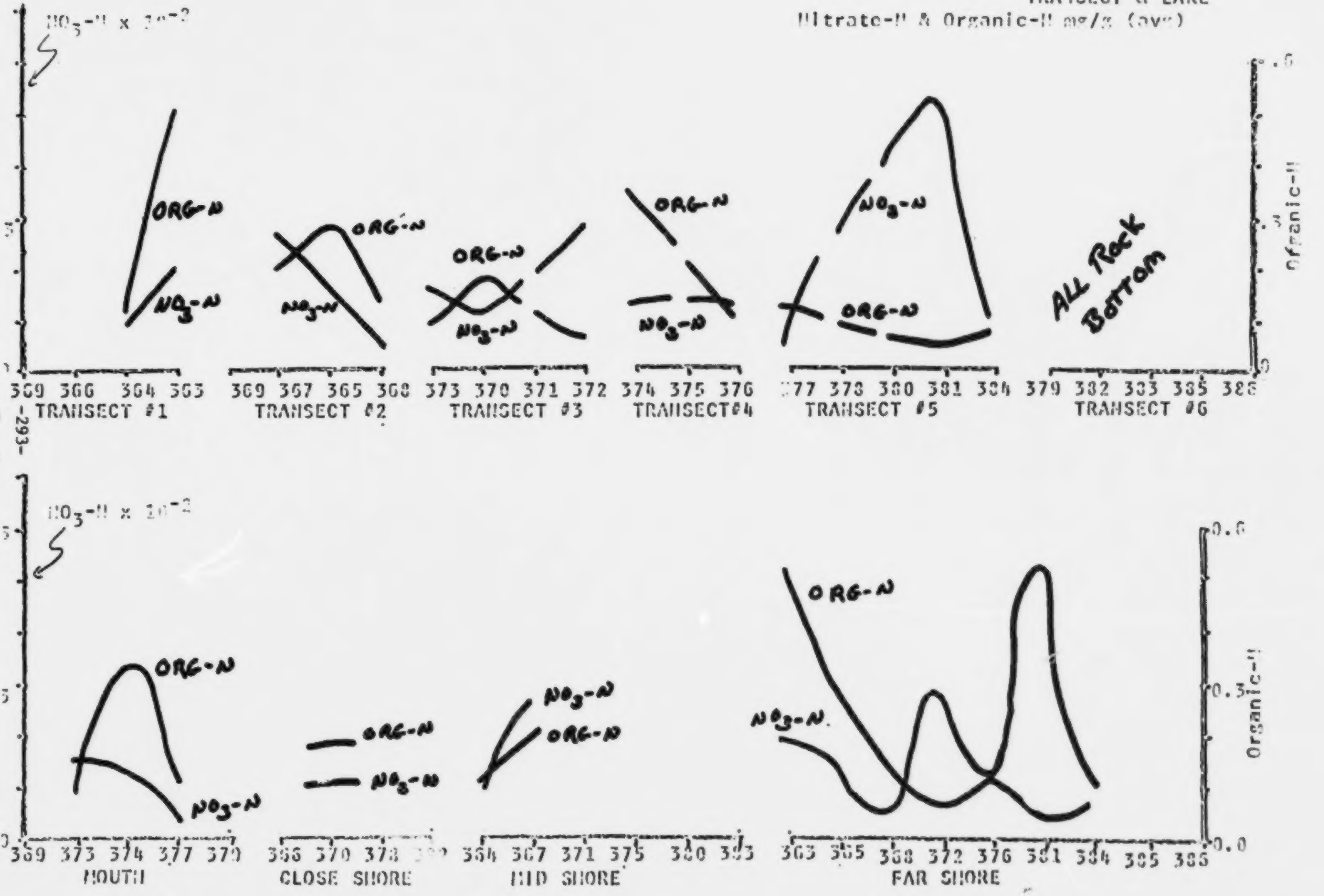
NITRATE NITROGEN (mg/g)
and
ORGANIC NITROGEN (mg/g)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE

Nitrate-N & Organic-N mg/l (avg)



-29-3-

Figure 23

MEAN VALUES

AMMONIA NITROGEN (mg/g)

and

TOTAL NITROGEN (mg/g)

NIAGARA SEDIMENTS

1972 IFYGL (NIAGARA RIVER)

TRANSECT & LAKE

Ammonia-N & Total-N mg/l (avg)

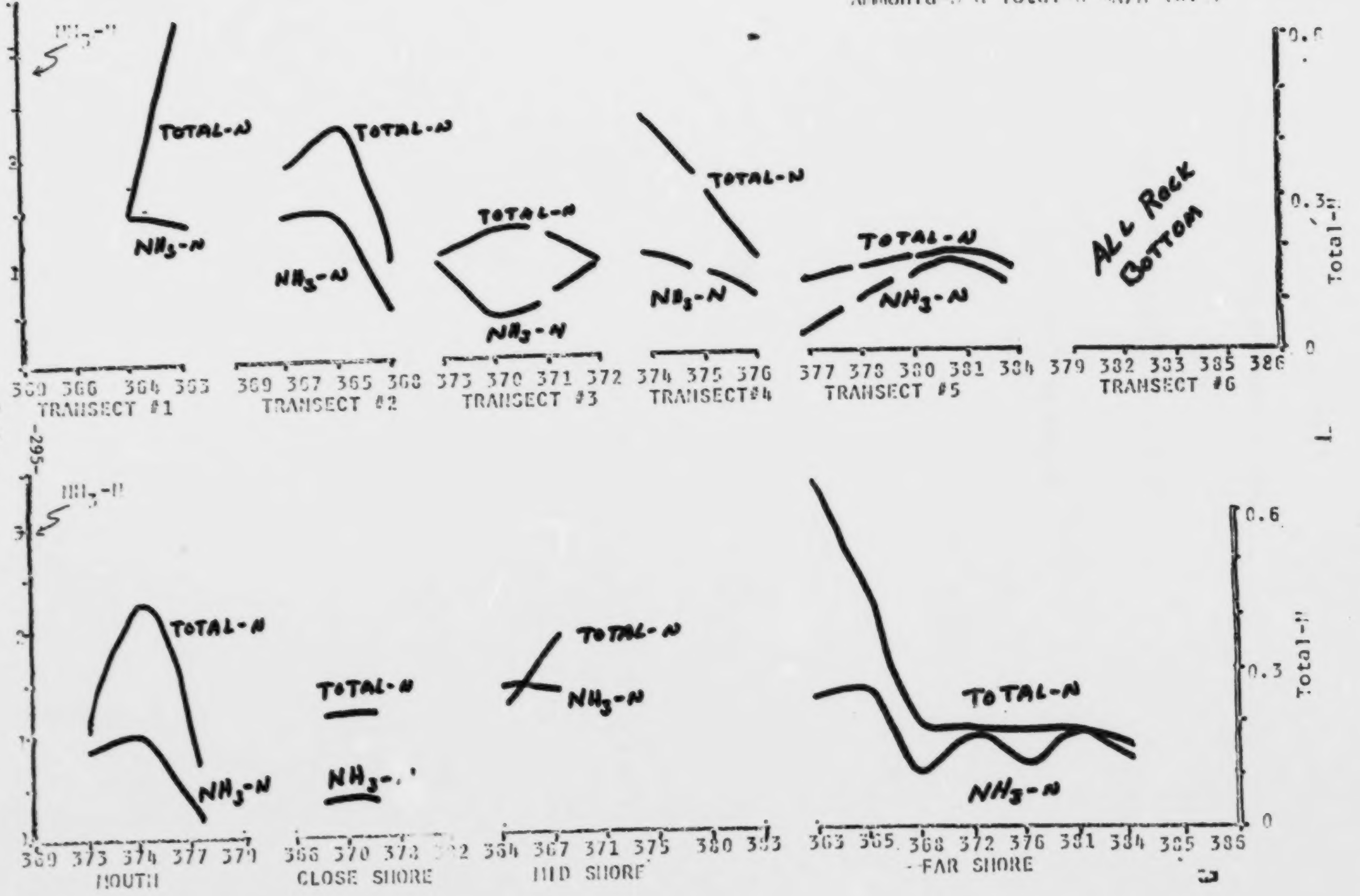


Figure 24

MEAN VALUES

DISSOLVED PHOSPHORUS (mg/g)

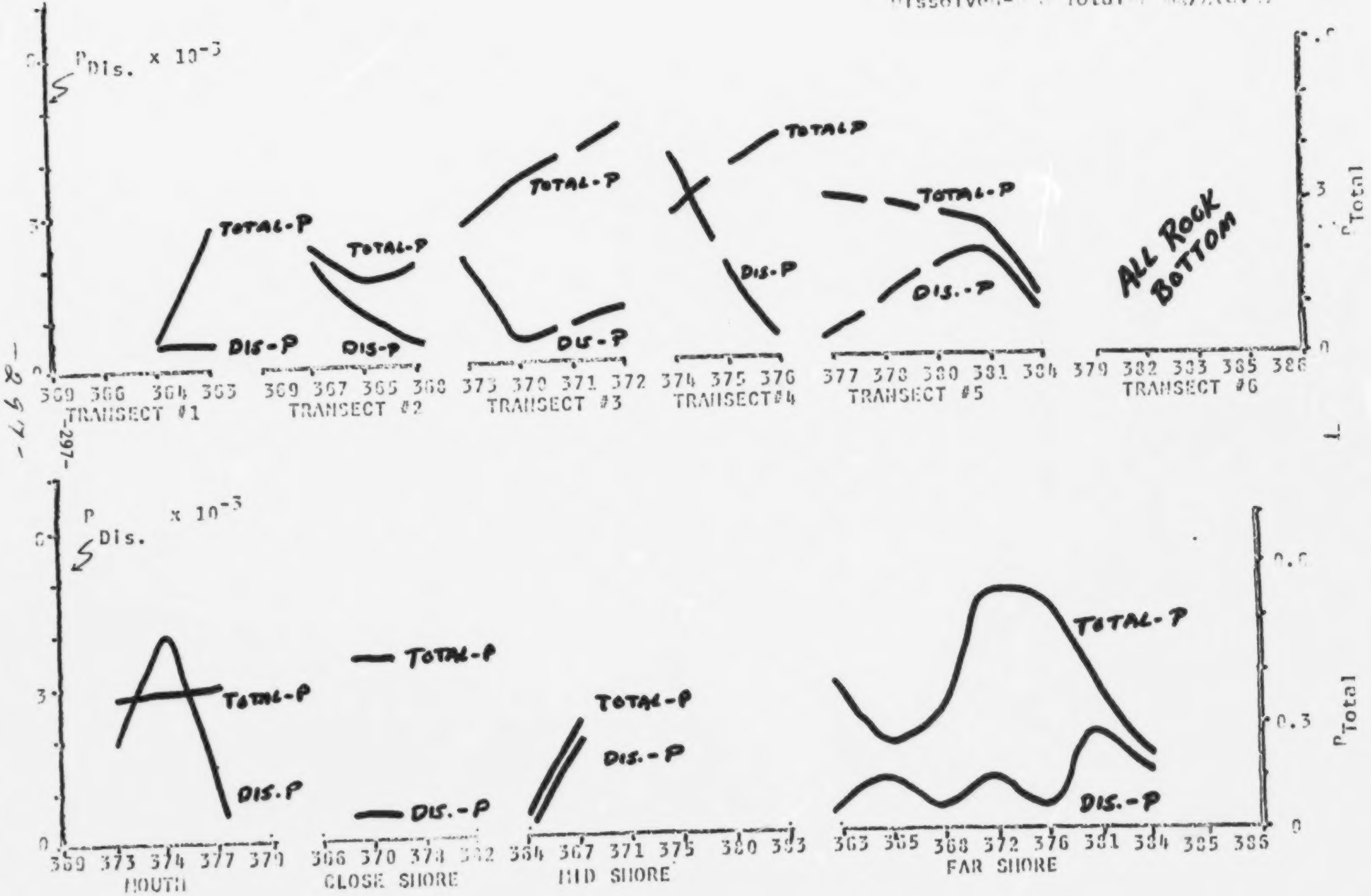
and

TOTAL PHOSPHORUS (mg/g)

NIAGARA SEDIMENTS

1972 IFYGL (NIAGARA RIVER)

TRANSECT & LAKE
Dissolved-P & Total-P mg/l(avg)



-297-

Figure 25

MEAN VALUES

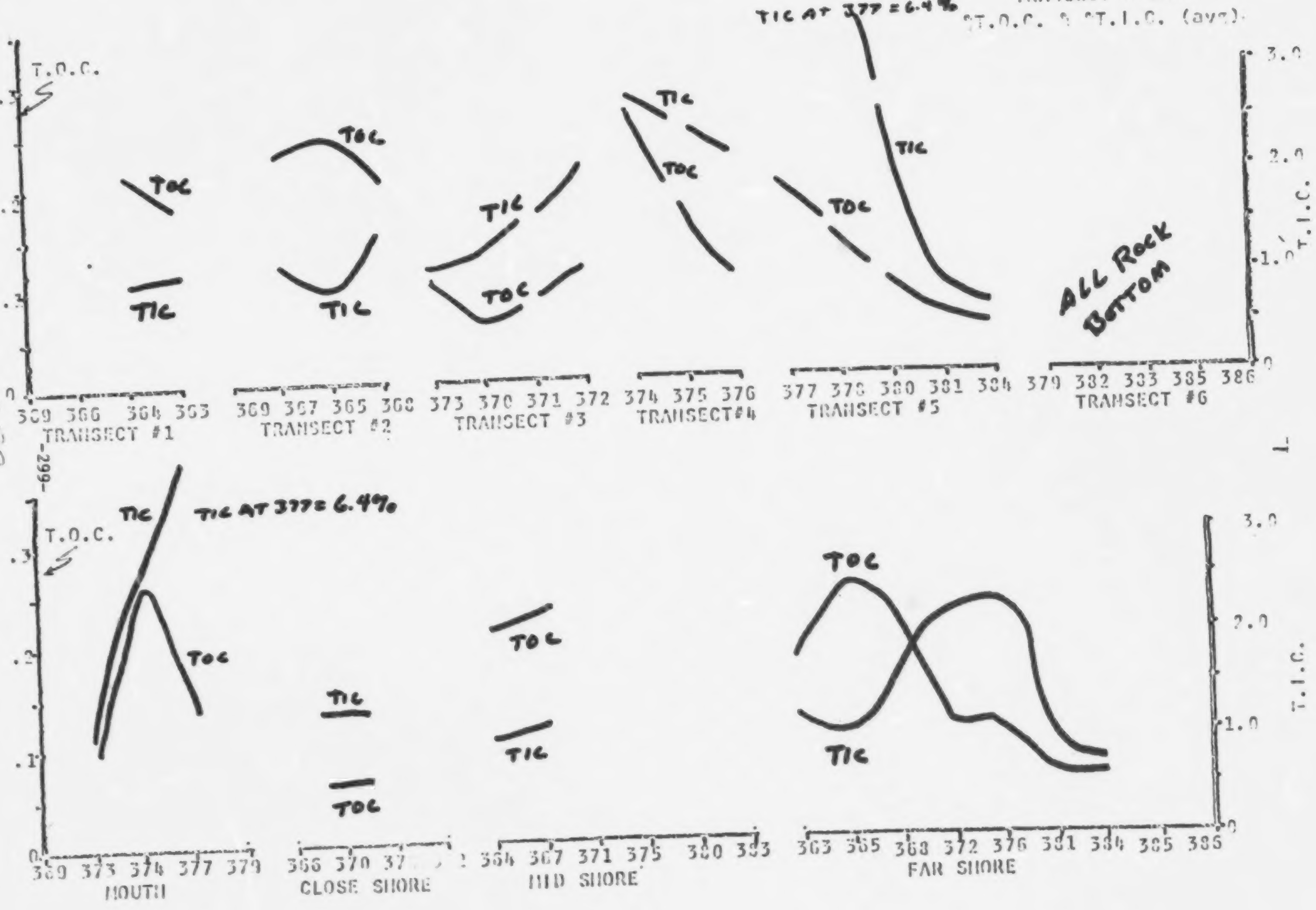
PERCENT TOTAL ORGANIC CARBON
and
PERCENT TOTAL INORGANIC CARBON

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE

%T.O.C. & %T.I.C. (avg)



-299-

Figure 26

MEAN VALUES

IRON (µg/g)

and

MAGNESIUM (µg/g)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE
Iron & Magnesium ug/m (avg)

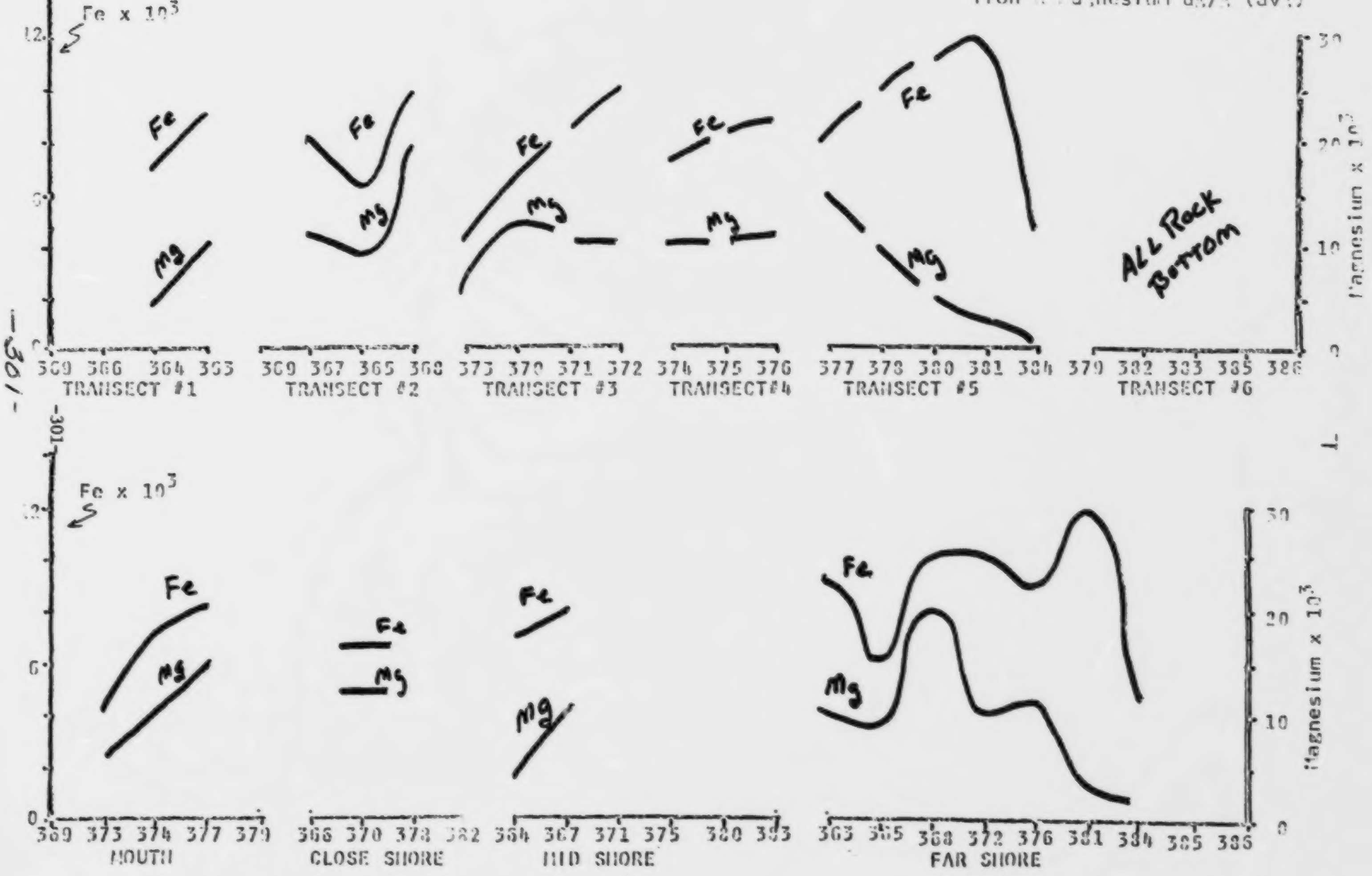


Figure 27

MEAN VALUES

MANGANESE ($\mu g/g$)

and

ZINC ($\mu g/g$)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE

Manganese & Zinc ug/g (avg)

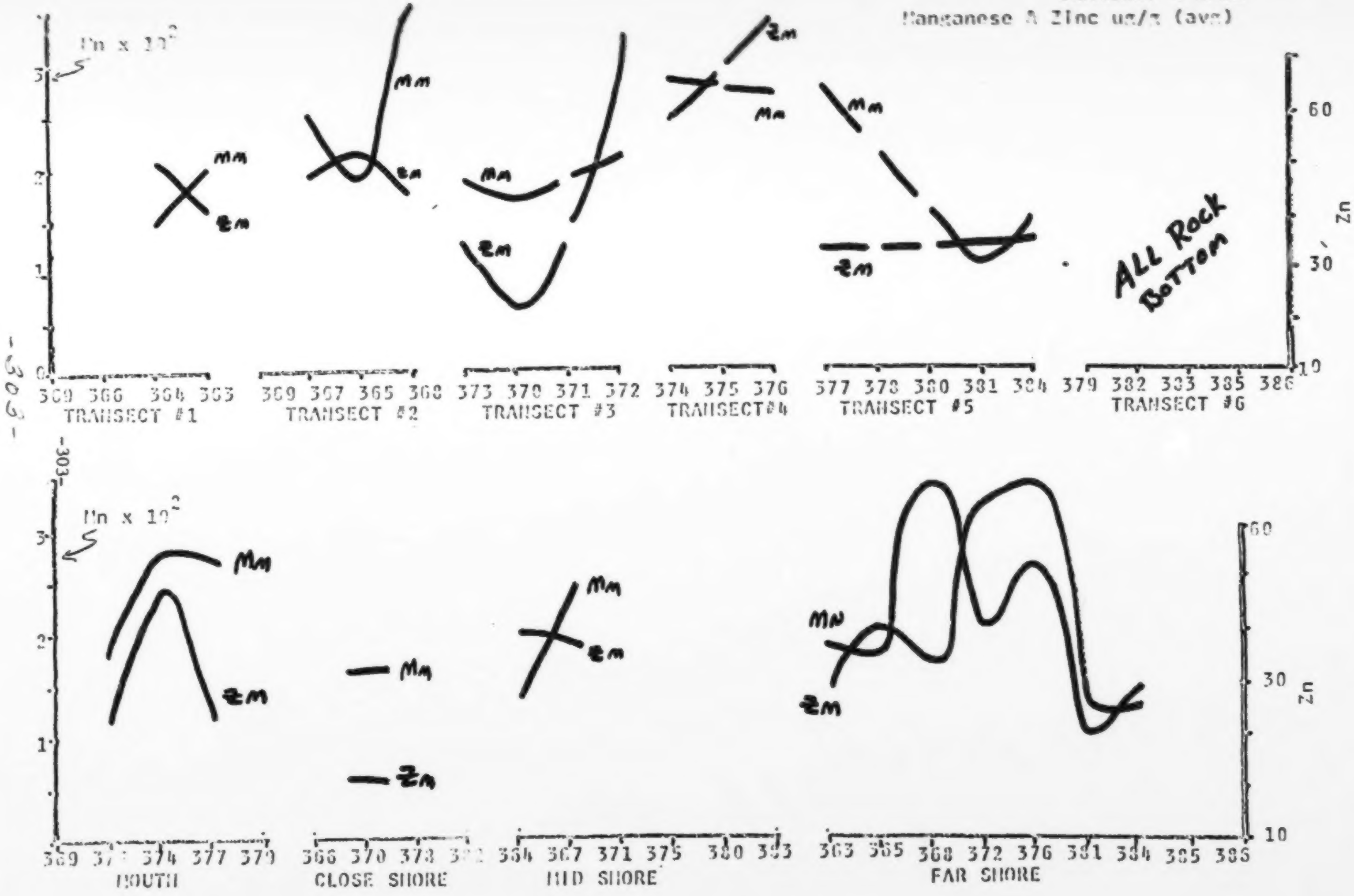


Figure 28

MEAN VALUES

COPPER (μg/g)
and
LEAD (μg/g)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE
Copper & Lead ug/g (avg)

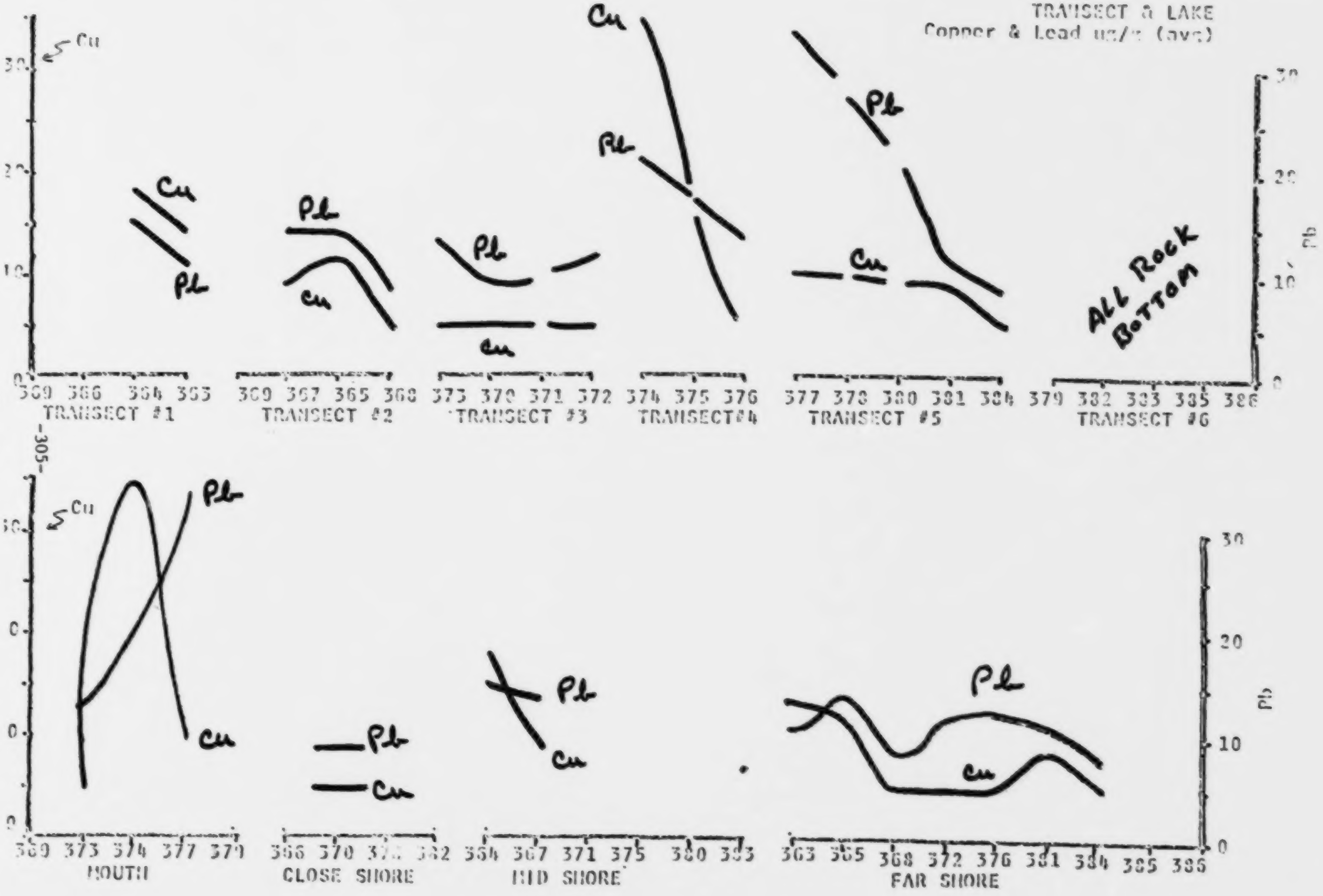


Figure 29

MEAN VALUES

CADMIUM (μg/g)

and

CHROMIUM (μg/g)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE

Cadmium & Chromium ug/g (avg)

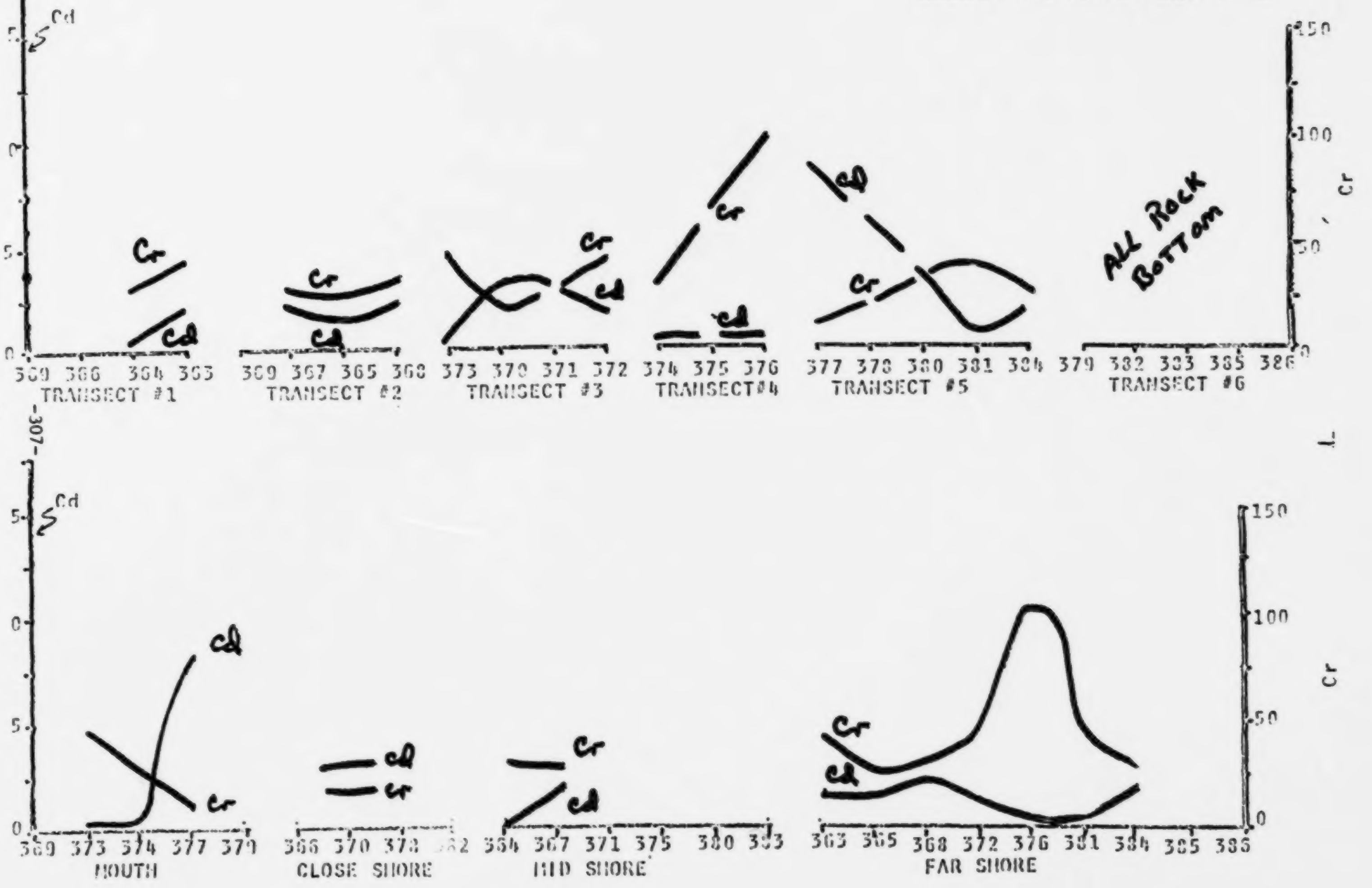


Figure 30

MEAN VALUES

NICKEL (µg/g)

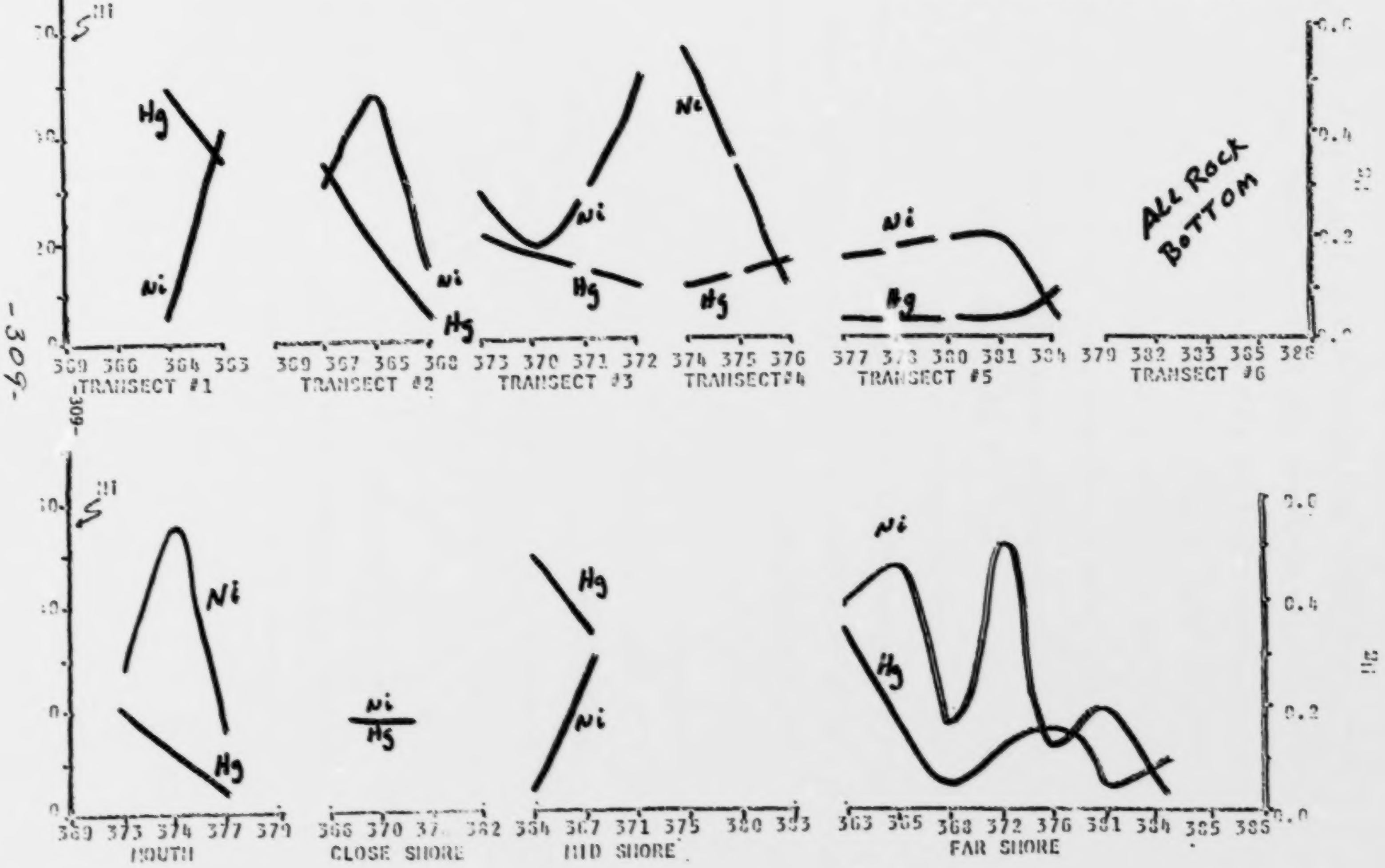
and

MERCURY (µg/g)

NIAGARA SEDIMENTS

1972 IFYGL(NIAGARA RIVER)

TRANSECT & LAKE
Nickel & Mercury ug/g (avg)



increased in distance from the shore. The nitrate and ammonia nitrogen values ranged greatly but were consistently higher at the 8 km stations. The organic nitrogen and total nitrogen were higher at the 8 km stations and between the Niagara and Genesee River plumes at the 4 km stations. The dissolved phosphorus concentrations of the 4 km stations were lower than the 8 km sites. Dissolved and total phosphorus values were relatively constant at 0.005 mg/g and 0.5 mg/g respectively. The TIC-TOC contents of the sediment were highest at the 4 km stations except at the Niagara River. Apart from the Niagara River the TIC-TOC concentrations were relatively constant at about 1.0% at the 4 km stations, approximately 0.5% TIC and 1.2% TOC at the 8 km stations.

In terms of metals, the influence of the Niagara River was greatest at stations 205 and 208. In general, all the metals had high concentrations at the 8 km stations decreasing slightly to the east. At the 4 km stations the concentrations were low near the Niagara River, increased sharply just east of the Niagara River and decreased slowly towards the Genesee River. The near-shore stations showed little influence from the Genesee River since all the sampling points, with the exception of one transect were taken on the west side of the river. East of the Genesee River, there was a slight increase at station 244 for all parameters measured. Zinc concentration increased sharply at this near-shore station.

Discussion of the 1/2 km stations is difficult since only five (5) of the proposed fifteen (15) stations yielded any analyzable sediment. Of these 5 stations, the 3 west of the Genesee River were sampled only once.

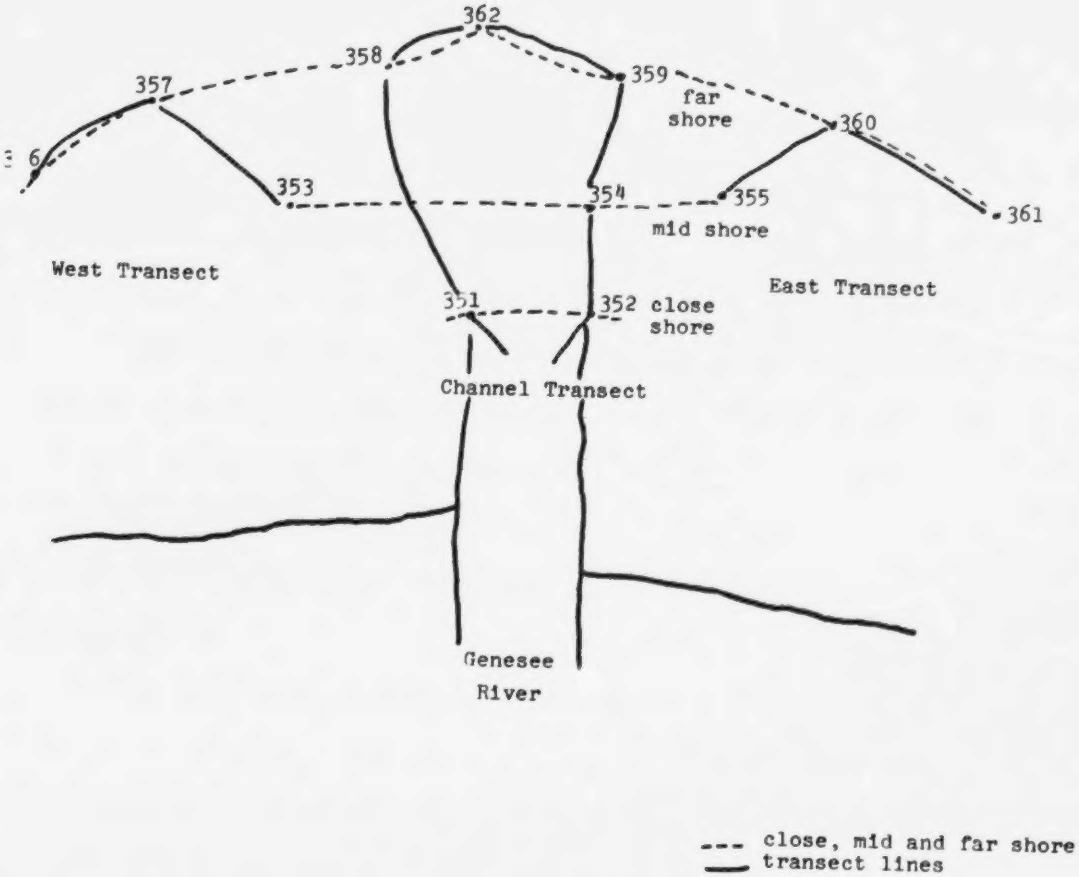
No temperature correlation can be attempted since the maximum temperature variation is only 3°C. During the first sampling the water was isothermal at 3°C. During the other samplings the lake was stratified and the sediment water interfact temperature were 5-6°C.

The only areas which would show temperature variations were the 1/2 km stations (being above the thermocline) but unfortunately all of these sites could not be sampled.

The only seasonable variation observed was the phosphorus content between the spring and fall samplings. During the spring and fall the phosphorus

Figure 31

GENESEE RIVER MOUTH SAMPLING SITES


362
358
357
356
359
far shore
360
353
354
355
361
mid shore
West Transect
East Transect
351
352
close shore
Channel Transect
Genesee River
close, mid and far shore
transect lines

concentrations were considerably higher.

For the sake of discussion the stations at the mouth of the Genesee River have been grouped into three (3) zones - West Transect, Channel Transect and East Transect - on an East-West plain and three (3) zone-close shore, mid-shore and far-shore - on a north- south plain. This is shown on Figure 31.

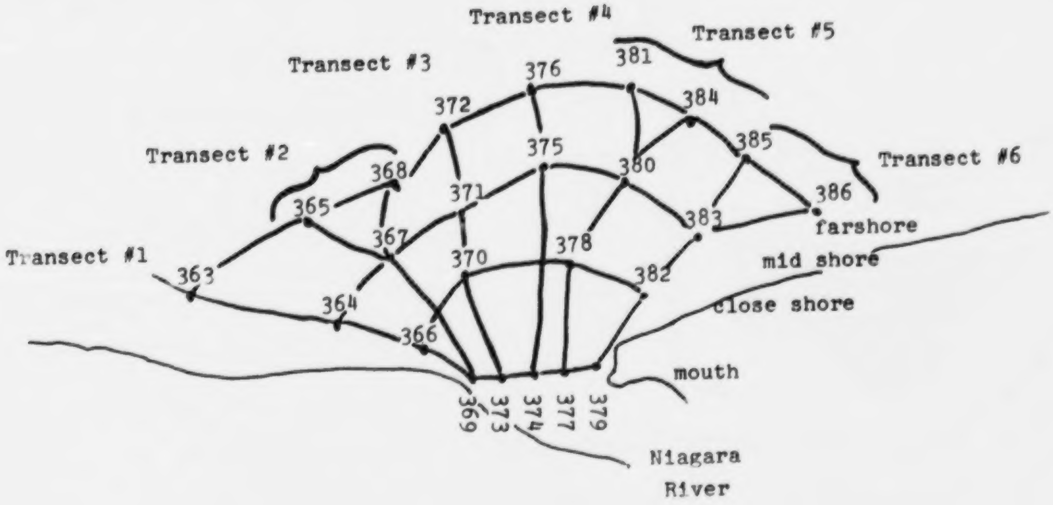
The benthic chemical conditions at the mouth of the Genesee River (Figure 31) were quite similar to those of the near-shore zone. The sediment, unlike that of the Niagara River area, was a sandy ooze. Percent dry weights were all being 60-70% except for one station, 355, which was considerably higher. The percent volatile solids are quite consistent in the channel transect and in the far shore stations. Percent volatile solids were lower on both sides of the channel transect and at the mid-shore stations. The nitrate nitrogen concentrations ranged from station to station but except for station 356 the values all fell between 0.2-0.4 mg/g. The organic and total nitrogen content was high at the far-shore stations and in the channel transect. The east transect had a high value at station 360 but the other two were low. The organic nitrogen content in the west transect increased with depth of water. The ammonia nitrogen concentrations were highest in the channel transect especially at the close shore. The other ammonia values were relatively constant at 0.15-0.20 mg/g. The total phosphorus concentrations were also relatively constant (.5-.75 mg/g). The dissolved phosphorus content was quite high (.003 -.006 mg/g) in channel transect, particularly at the mid and far shore stations.

Seasonable variations were observed in the phosphorus concentrations. The phosphorus values were 25 to 50% higher in the spring and fall, especially in the close and mid shore stations, than in the summer. TOC concentrations were highest in the far shore stations. The content was relatively constant at all stations around the Genesee River. The TOC concentrations were particularly high in the east transect. These east transect sediment samples contained small amounts of what appears to be coal.

The iron concentrations were quite variable throughout the entire Genesee River sampling area. The far shore stations showed a decreased iron content from west to east. The highest iron concentration was

Figure 32

NIAGARA RIVER MOUTH SAMPLING SITES


Transect #4
Transect #5
Transect #3
Transect #2
Transect #6
Transect #1
376
381
384
372
375
385
368
380
386
371
365
367
383
378
370
382
363
364
366
369
373
374
377
379
farshore
mid shore
close shore
mouth
Niagara
River

noted at station 352, a close shore station.

Magnesium concentrations were highest in the close shore and again in the channel transect at the far shore stations. The magnesium concentrations were quite low in the west transect and increased steadily in the east transect away from the Genesee River.

Manganese and zinc showed a relatively constant concentration over the entire sampling area. Copper and lead also were constant over the entire sampling area with the exception of quite high values (30 μg/g Cu, 40 μg/g Pb) in the middle of the channel transect at the mid and far shore stations. The same was true of cadmium and chromium except for high concentrations of stations 352, 354, 356 and 358 (all in the channel transect). N concentration was low, except in the channel transect. Stations 352 and 358 were especially high. The mercury concentrations were quite low (~0.2 ug/g) except in the west portion of the channel transect at the mid and far shore lake stations.

For purposes of discussion the Niagara River stations also have been grouped into four (4) east-west and six (6) north-south transects (Figure 32). One must realize that any conclusions of the following data must be general at best, since eleven (11) of the twenty-four (24) proposed stations all of a transect 6 had a rock bottom.

The sediment collected from the Niagara River were all sandy; with high percent dry weights. The percent volatile solids in the center of the mouth of the Niagara River were the highest of any station in the project. The far shore volatile solids were consistently between 2-4%. Nitrate nitrogen content was high (.02 mg/g) in the center of the river mouth and low on either side. To the west of the Niagara River (Transect 1) the nitrate nitrogen concentration was high but decreased towards the river mouth and increased again on the east side of the mouth. The nitrate nitrogen concentration at Station 381 (a far shore station) was particularly high. The organic, ammonia and total nitrogen values were high in the center of the river mouth and on the west side of the river but relatively low at the other sites.

Total phosphorus concentrations at the river mouth were low but increased with greater depth of water. The values of the far shore stations directly north of the river mouth were quite high and decreased on either side of these stations. The dissolved phosphorus contents were high in the center of the mouth of the Niagara River and relatively low at all the other sampling sites.

TIC-TOC concentration varied over the sampling area. The highest observed TOC contents were west of the Niagara River and decreased steadily to the east. TIC values were particularly high at the river mouth (374 and 377). These were the highest TIC values measured during the study. TIC values also were high in the far shore stations directly north of the river mouth.

Iron concentrations were low at the mouth of the river and increased on all transects with greater depth of water. Magnesium concentrations also were low in the Niagara River sampling area.

Zinc and manganese also were low in this area except for the stations directly north of the mouth.

Copper and lead contents were high at the mouth of the river, particularly in the center but decreased sharply in the deeper waters.

Cadmium and chromium were low in this area with a few exceptions. Cadmium was high at station 377 (at the mouth of the river) and chromium was high at station 376, a far shore station directly north of the mouth. The other values for cadmium and chromium were relatively constant.

Nickel concentrations were high at the center of the mouth of the Niagara River and to the west of the river. Station 372, a far shore station, north of the mouth also was quite high.

Mercury concentration also was low in this area except for those stations west of the Niagara River.

Little seasonable variation in ion concentration was noted in the Niagara River area.

More intensive analysis of these data, including contrasting sediment and water chemistry, and biological measurements will be made when the information has been entered into STORET.

B. Water

1. Objectives

The objectives of this phase of the project essentially were the same as those described above for sediment.

2. Plans vs. Accomplishments

As stated in the proposal by the GLL to EPA, water samples were gathered with a 4.1 liter Van Dorn Collection Bottle from one (1) meter below the surface, mid-depth and one (1) meter above the bottom during each near-shore and river mouth cruise for a total of more than two thousand (2000) collections. The pH, ammonium ion content and total alkalinity of each sample were determined immediately after the water was collected. The water samples were preserved in order that the quantity of each of the following proposed parameters could be ascertained at EPA's Rochester Field Station: nitrate, nitrite, organic and total nitrogen; suspended, soluble and total phosphorus; total organic carbon; sulfates; chlorides; silicon dioxide; phenols; calcium; sodium; potassium; heavy metals (iron, magnesium, mercury, lead, zinc, chromium, selenium, cadmium, nickel, manganese and copper); pesticides (DDT, DDE, DDD, lindane, aldrin, dieldrin, toxaphene, endrin, toxaphene, chlordane, heptochlor and heptochlor expoxide).

The ammonium measurements were abandoned when it was determined that they could not be measured with any degree of confidence with a specific ion electrode.

3. Status

The alkalinity and pH values were forwarded to EPA for insertion into the IFYGL data bank.

The status of the water analyses being conducted by EPA-Rochester is unclear. No data has been entered into STORET.

4. Summary of Results

Few conclusions can be drawn due to the fact that the results of the analyses concerning those parameters measured by EPA-Rochester area were not available at this writing.

Examination of the results of tests made in the field showed that the alkalinity ranged from 95-113 ppm with no consistent pattern in the vertical or horizontal profiles or between the values observed at the same station on different cruises, in the near-shore zone or at the mouth of the Niagara River. However, at the mouth of the Genesee

River the surface waters had an alkalinity of up to 124 ppm while the measurements of about 100 ppm were found at the mid and bottom waters.

The pH differed by as much as 0.5 units between the 1/2 and 8 km stations with the lower values found at the latter collection sites. During the spring there was little difference in the pH with depth at the near-shore and Niagara River stations. However, when the lake was stratified, the pH was higher above the thermocline than below. After the stratification was destroyed, there again was little difference between the pH from the surface to the bottom.

The pH of the Genesee River surface was consistently lower than lower depths irregardless of the season.

IV. PHYSICAL STUDIES

A. Ship-Board

1. Objectives

This phase of the survey was designed to determine the changes in oxygen concentrations, temperature and light transmission, each measured on vertical and horizontal plains. From the above the location and duration of the thermal bar and thermocline was to be calculated along with the nature and extent of the plumes from tributaries discharging into the Welland-Rochester near-shore zone.

2. Plans vs. Accomplishments

The proposed measurements to be made at each station on every cruise included: oxygen-temperature profile, light (transmission) profile, pH and conductivity at the surface, mid-depth and bottom. All of the above was accomplished with the exception that the light meter (submarine photometers) malfunctioned on the second Genesee River mouth sampling and was not repaired until the last cruise in 1972 (27-29 November).

3. Status

All data has been calculated (i.e., percent transmission, conductivity adjusted to 25°C, etc.) and sent to EPA, Grosse Ile, for entering in STORET. At this time. this information is not ready for retrieval.

4. Summary of Results

The GLL has been awaiting the entry of the data in STORET in order to use the capacity of the latter system to plot the mean, median, standard deviation, co-efficient of variance, variance and standard error via the Invent Program. Hence, extensive analysis of this information has not been done. However, some generalizations can be drawn from the raw information.

A thermal bar was present during the 18 April through 3 May 1972 period. It extended between stations 202 (4 km) and 203 (3 km) and 204 (1/2 km) and 205 (4 km) to the mouth of the Niagara River. To the east it reappeared to the shoreward-side of station 210 (1/2 km), extended between stations 213 (1/2 km) and 214 (4 km) and again to the shore south of station 216 (1/2 km). From the latter, it was present between the 1/2 and 4 km stations through 219 (1/2 km) and 220 (4 km). East of the 234 (1/2 km), 235 (4 km) and 236 (8 km) chain it intersected the shore to the south of station 337 (1/2 km). To the east the thermal bar again was found between the 1/2 and 4 kilometer stations.

On the 10-23 May 1972 cruise the bar had moved lakeward. It was observed between stations 202 (4 km) and 203 (8 km). However, instead of moving to the shore, it extended to the north of stations 206 (8 km) and 209 (8 km). To the east it stretched just below the 4 km stations 211, 214, 217 and 220 from which it was found between the 4 and 8 km stations through 238 and 239. It was north of 8 km stations 243 (8 km) and 245 (8 km).

A thermal bar was not observed again in 1972.

With respect to vertical temperature stratification, isothermal conditions were observed on the 18 April through 3 May and 10 through 23 May 1972 cruises. During the 19-28 June cruise a thermocline was present between 10 and 15 meters at all stations. The stratification was found between 15 and 20 meters on both Cruise IV (12-21 July) and V (25 July - 2 August). On the 5-13 September cruise the thermocline was observed between twenty (2) and twenty-five (25) meters at the 4 and 8 km stations. However, the thermocline had risen to 15 meters at the 4 and 8 km stations on cruise VII (21 September - 4 October). On Cruise VIII the thermocline had sunk below 45 meters. The last stratification was noted at station 220 and 30 October. On Cruise IX (6-22 November) and X (11-14 December) the water was isothermal with slightly warmer conditions found at the 4 and 8 km stations.

No significant difference was observed in the dissolved oxygen profiles between the 1/2, 4 and 8 km stations on any single cruise. This includes the period when thermal stratification was present. Contrasting the changes with the seasons, the dissolved oxygen decreased from 13-14 ppm in the spring to 10-11 ppm in the summer. It increased to 11-12 ppm in the fall and 12-13 ppm by the winter.

Conductivity (300-310 µmohs) was fairly uniform from the surface to the bottom prior to stratification. There also was little variation between the 1/2, 4 and 8 km stations or from one end of the near-shore zone to the other. However, after stratification the epilimnetic waters had a conductivity of

280-300 µmohs while the hypolimnion was 300-325 µmohs. This condition persisted until Cruise XIII at which time the vertical mixing occurred and the conductivity returned to 300-310 µmohs.

B. Other Physical Measurements in Study Area

1. Objectives

Other researchers in the IAGLR Program also made measurements and collections in the same regions as the GLL. Each of these studies had individual objectives, which can be obtained from the Project Director of each project, in addition to providing information that could be used by other researchers.

2. Plans vs. Accomplishments

The direction, duration and intensity of currents in the Welland-Rochester near-shore area were to be made by scientists at the Rochester Field Office of the Environmental Protection Agency and the University of Rochester. The GLL has contacted these researchers and is awaiting inputs on the nature and extent of their data.

The discharges from the Niagara and Genesee River also were measured. These data also are being sought as is the information from the meterological towers in and near the near-shore zone.

3. Status

Unknown.

4. Summary of Results

Unknown.

V. BUDGET VS. ACCOMPLISHMENTS

The sediment chemistry and physical phases of the study are on schedule. The analyses of benthos is somewhat behind but should be completed by the termination of the grant. The phytoplankton and zooplankton identification and quantification will not be finished by the end of the grant due to the problems explained above. A three (3) month extension is being requested. There should be sufficient funds left in the 1973-74 grant to cover the estimated costs of $6324 (1 Research Assistant for three months @ $833/month plus fringe benefits of $450 and overhead of $374.00; one consultant - Mrs. Sharon Czaika - 3 months @ $1000/month).

The above savings in the 1973-74 grant come as a result of the fact that the consultant, proposed to be hired under the 1973-74 award, to assist with the development of a mathematical model of the near-shore zone was not added to the GLL staff. This was due to the fact that one of the major inputs to the proposed model - specifically the results of the 1972 and 1973 water chemistry - has not become available. Until this information, along with the results of the measurements in the GLL's study area by other IFYGL researchers, is completed, a comprehensive model cannot be constructed. Since these data may not be available by the end of the period of 1973-74 award, a 1974-75 grant proposal (for approximately

$10,000) to support the modeling will have to be made or the model will have to be abandoned by the GLL.

A REMOTE SENSING PROGRAM FOR THE DETERMINATION OF CLADOPHORA DISTRIBUTION IN LAKE ONTARIO (IFYGL)

Grant Number 800778

F. C. Polcyn
Environmental Research
Institute of Michigan

-329a-

A REMOTE SENSING PROGRAM FOR THE DETERMINATION OF CLADOPHORA DISTRIBUTION IN LAKE ONTARIO (IFYGL)

GRANT NUMBER 800778

A. REVIEW OF THE SUBJECT UNDER STUDY

This investigation is designed to contribute to the U. S. Biological and Chemical program in Lake Ontario (IFYGL) by providing data regarding the distribution of *Cladophora* along the U. S. shoreline of the lake.

Any attempt to delineate the distribution of *Cladophora* on a large scale basis must face the issue that conventional methods of data acquisition are totally inadequate for this purpose. Therefore, the present study is designed to exploit the capabilities of remote sensing technology for mapping submerged aquatic vegetation. The program includes multispectral and photographic data collection, using the ERIM remote sensing aircraft, and computer processing of the multispectral scanner data to map the distribution, calculate areas, and estimate biomass of *Cladophora*.

B. PLANNED OPERATION VERSUS ACTUAL OPERATION

The original program provided for one multispectral aircraft data collection mission during the month of June 1972 along the entire shoreline of Lake Ontario. The intent was to acquire approximately 500 miles of data along a flight track 1500 feet wide for subsequent processing on a sampled basis. The program also provided for limited data processing to establish the computer techniques best suited for routinely processing the data set.

Data were collected on June 20, 1972 along the U. S. shoreline from Niagara to Stony Pt. at the eastern end of the lake. Poor weather conditions forced cancellation of the plan to collect data over Canadian portions of the lake. Because of very unfavorable field conditions in June along portions of the flight line, particularly between Rochester and Stony Pt., a second mission was recommended for the month of July. Upon consultation with the EPA project monitor, the original plan for data collection over Canadian waters was abandoned in favor of a second mission along the U. S. shore. This mission was carried out on July 31, 1972. A Canadian decision to collect data over Canadian waters provided added justification for restricting activities to U. S. portions of the lake.

C. COST TO PROGRAM BECAUSE OF STUDY DEVIATION

The modification described above had no effect in terms of cost to the contract. The original plan of operations provided for one data collection mission consisting of 500 data miles. The subsequent modification resulted in two missions for a total of approximately 500 miles. Likewise the modification will have no effect on the current data processing phase of the program.

D. STATUS OF THE PROGRAM

The first year of the program was devoted to multispectral data collection and the determination of the most suitable computer-implemented _Cladophora_ mapping procedures.

Two multispectral data collection missions were completed along the U. S. shoreline, June 20, 1972 and July 31, 1972, from altitudes of 1300 ft and 2000 ft respectively. Twelve channel multispectral scanner data were recorded in addition to black-white and color photography. Four scanner channels have been reproduced on film strips. These are: 0.43 - 0.48 μm, 0.52 - 0.57 μm, 0.61 - 0.70 μm, and 9.3 - 11.7 μm.

Preprocessing of the scanner data had been undertaken at selected areas, and computer processing of a section of the New York shoreline was completed.

A request was forwarded to EPA for ground truth data at a number of locations in the study area. This information is required in the data processing phase of this investigation. To date, this information has not been received.

The objectives of the program for the first year were to collect multispectral data and to demonstrate the ability to map Cladophora. These objectives have been realized.

E. AREAS OF PROGRAM WHICH ARE BEHIND SCHEDULE

None

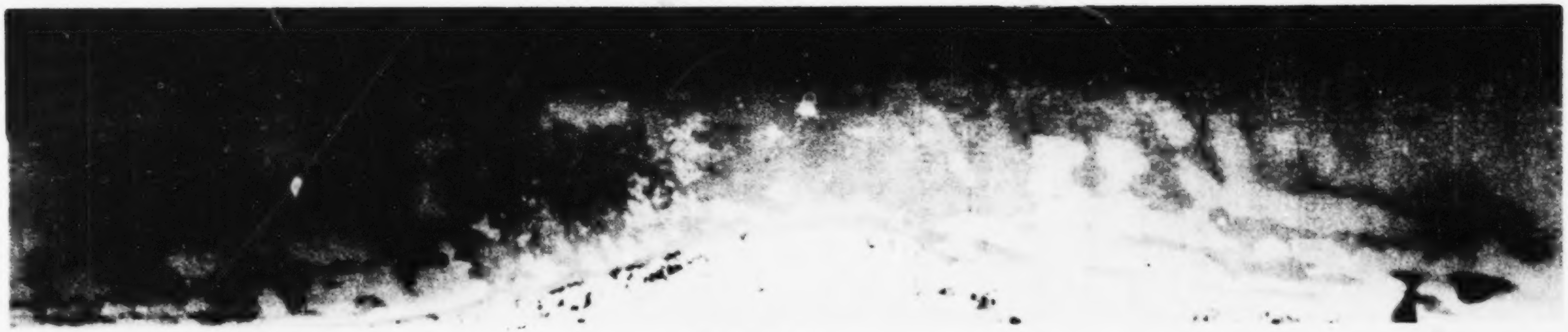
F. SUMMARY OF RESULTS TO DATE

In view of the fact that the second year of the program is devoted to computer processing of the data, the results of the first year effort presented herein are necessarily limited to selected examples.

Shown in Figures 1 and 2 is a portion of the New York shoreline in the vicinity of North Hamlin, New York. The dark areas visible in the 0.52 - 0.57 μm band are Cladophora beds. The upper band, 9.3 - 11.7 μm, depicts surface temperature variations at the time of the overflight.

Computer processing of a section of shoreline was completed and the area extent of Cladophora was calculated. Shown in Figure 3 is a digital map of a portion of the study area illustrated in Figure 2. The area shown is 470 meters by 1220 meters. Within this area, 430,344 sq meters or 75% of the bottom is covered by Cladophora. Ground truth data provided by EPA will be used to calculate standing crop expressed as weight per unit area.

9.3-11.7 µm



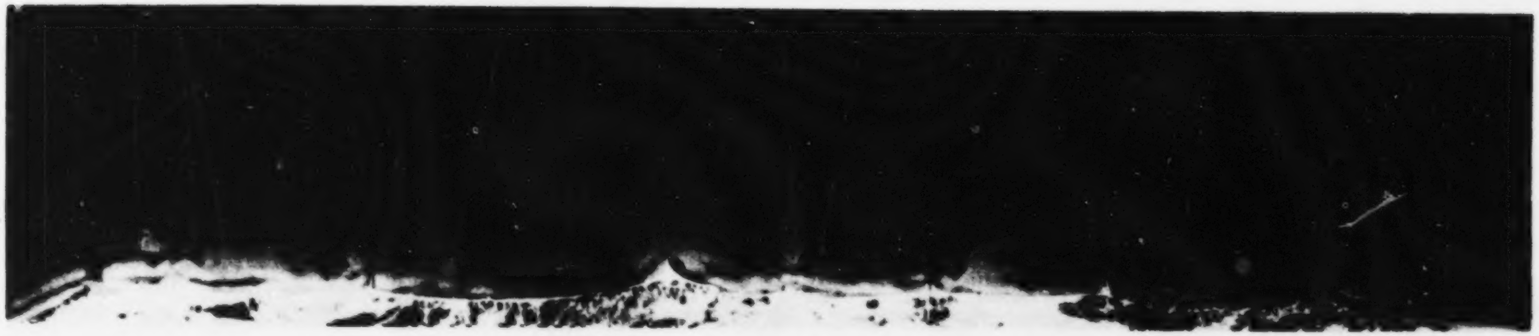
0.52-0.57 µm

MULTISPECTRAL IMAGERY—LAKE ONTARIO NEAR NORTH HAMLIN, N. Y.
20 JUNE 1972

FIGURE 1

Sheet 1 of 2 Sheets

9.3-11.7 μm

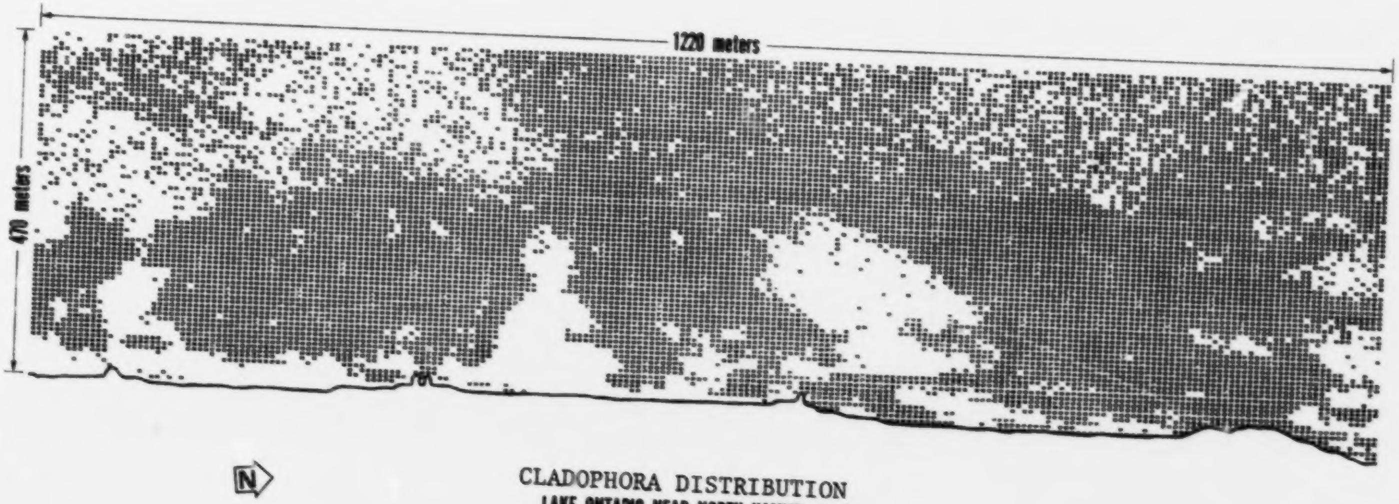


0.52-0.57 μm

MULTISPECTRAL IMAGERY—LAKE ONTARIO NEAR NORTH HAMLIN, N. Y.
20 JUNE 1972

FIGURE 2

Sheet 2 of 2 Sheets


1220 meters
470 meters
N

CLADOPHORA DISTRIBUTION
LAKE ONTARIO NEAR NORTH HAMLIN, N. Y.
Scene Date - 20 June 1972

FIGURE 3

*U.S.Government Printing Office: 1974 — 750-342/1047 Region 5-I